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MDC-TR-68-72

AIR FORCE MISSILE DEVELOPMENT CENTER
DIRECTORATE OF TECHNICAL SUPPORT

RAT SCAT RADAR CROSS SECTION MEASUREMENTS OF AN APOLLO COMMAND MODULE MOCK-UP

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November 1968

Prepared for
THE RADAR TARGET SCATTER DIVISION (RAT SCAT)
AIR FORCE MISSILE DEVELOPMENT CENTER, HOLLOMAN AIR FORCE BASE, NEW MEXICO
by
GENERAL DYNAMICS
Fort Worth Division

FRXM 69-06

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The Radar Target Scatter Division (RAT SCAT)
Air Force Missile Development Center, Holloman Air Force Base, New Mexico
by
GENERAL DYNAMICS
Fort Worth Division

FOREWORD

This Air Force report is based upon the actual radar cross section measurements made at the Radar Target Scatter Division (RAT SCAT) of the Air Force Missile Development Center. RAT SCAT is located on the Alkali Flats, Holloman Air Force Base, New Mexico. This Facility is operated and maintained by General Dynamics, Fort Worth Division, and is under the specific direction of the Air Force Missile Development Center. The AFMDC Project Officer is Captain George D. Locke, Jr. Correspondence pertaining to this report should be addressed to the attention of MDRT.

This technical report has been reviewed and is approved.

W. C. MC CORMICK, JR., Lt Colonel, USAF
Director of Technical Support

ABSTRACT

Radar cross section measurements of an Apollo Command Module mock-up were obtained at RAT SCAT. Measurements were taken at frequencies of 2200 and 5690 megahertz with both vertical and horizontal antenna polarizations. In addition, circular polarization and cross polarization measurements were obtained at 5690 megahertz. Target orientations measured were 0 degree pitch; 53, 106, 136 and 172 degrees roll. This report contains no analysis of the data.

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LIST OF FIGURES AND TABLES

SECTION I

INTRODUCTION

Radar cross section measurements of a mock-up of the Apollo Command Module were obtained during the period beginning 4 November 1968 and ending 8 November 1968. The purpose of these tests was to provide data to be used in assessing the ability of the manned space flight tracking network to skin track the command module.

The command module mock-up has basically a conical shape with a cone half-angle of 33 degrees. It is 8.75 feet long, has a base diameter of 13 feet and weighs approximately 3000 pounds. The model is shown mounted at 0 degree pitch, 172 degrees roll in Figure 1.

The target orientations measured were 0 degree pitch with 53, 106, 136 and 172 degrees roll positions. Measurement frequencies were 2200 and 5690 megahertz. The 2200 megahertz measurements were taken with vertical and horizontal antenna polarizations. Those obtained at 5690 megahertz were at vertical, horizontal and circular polarizations. In addition, a measurement was taken at 5690 megahertz with cross polarization (transmit vertical - receive horizontal) for the 0 degree pitch, 172 degrees target roll orientation.

The measurements made and the data contained herein have been certified in terms of quality, repeatability and accuracy by Air Force representatives on site (AFMDC, MDRT).

The measurements were requested by the National Aeronautics and Space Administration, Manned Spaceflight Center, Houston, Texas, in REFSRAM 69-06.

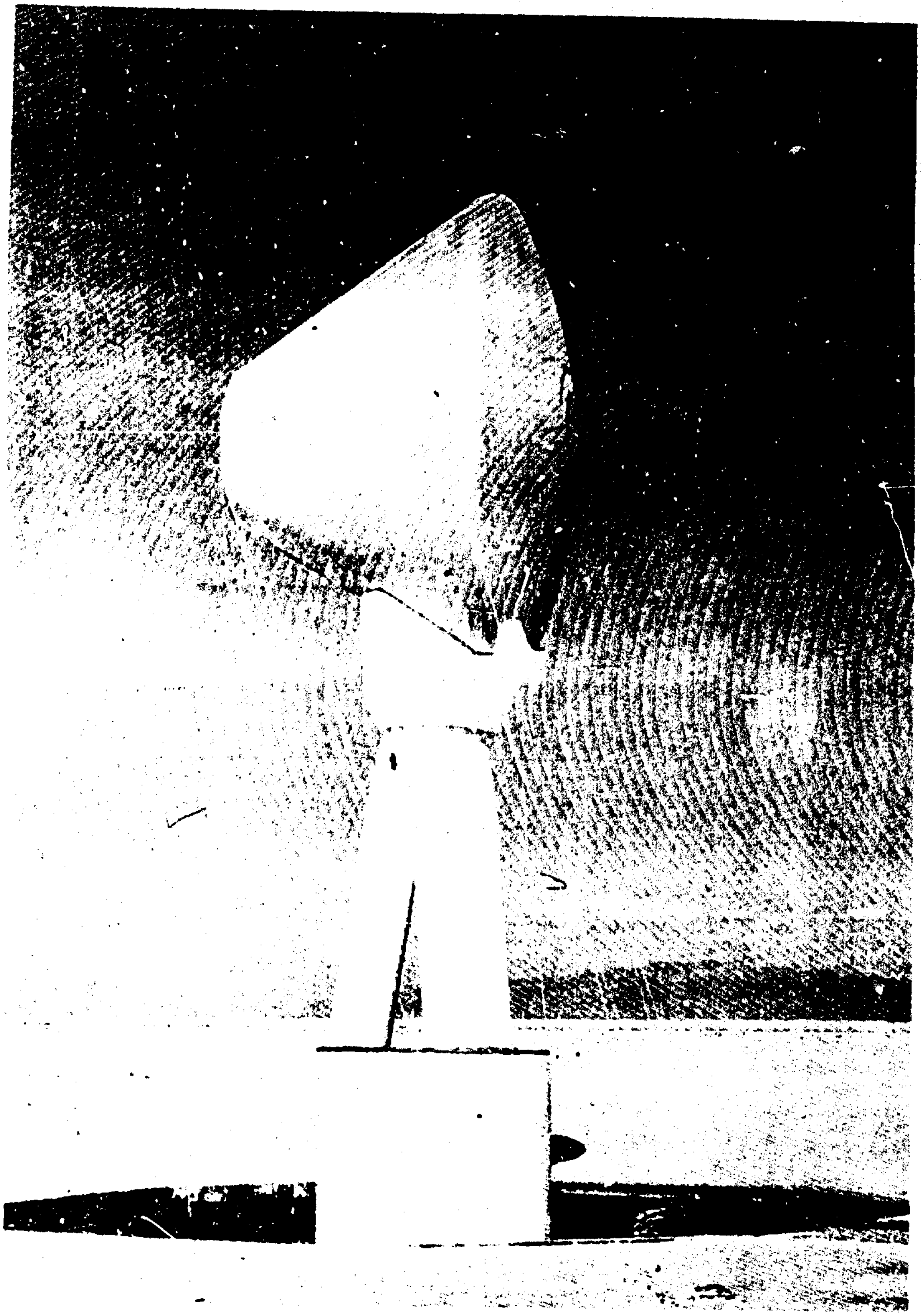


Figure 1 SIDE VIEW OF APOLLO COMMAND MODULE MOCK-UP

A general description of the RAT SCAT site and the operational procedures is contained in Appendices A and B.

SECTION II

TEST CONDITIONS AND RESULTS

System Parameters

Measurements were conducted during this program using one of the standard RAT SCAT operating ranges (2458 feet) and electronic equipment located in the operations building. The target was mounted at a height of 20 feet. Antenna heights were 13 feet and 4.5 feet at frequencies of 2200 and 5690 megahertz, respectively. The antennas utilized were 6-foot parabolic dishes having appropriate feeds for the required frequencies and polarizations. Transmitter pulse repetition frequency was 1 kilohertz with a pulse width of 0.25 microsecond. The peak power was 1000 watts. Receiver sensitivity was approximately -94 dBm and the range-gate width was 0.2 microsecond.

The target support structure was constructed from expanded polystyrene materials. It consisted of a tripod affixed to a cylindrical base, and a transition piece which mated the target to the tripod (see Figure 1). Background measurements were obtained to determine the radar return from the support structure and insure that the presence of the support would have minimal effects on the target data. Background runs are indexed in Table I, Data Plot Index. Figure A-2 contains a graph showing the maximum error which can be induced in target data by background interference.

The measurement taken with the antennas cross polarized (transmitter vertical - receiver horizontal) is a measurement not only of the cross polarized cross section of the command module, but also

of an unwanted isolation-limited (approximately 35 dB) linearly polarized return from the target. The presence of this unwanted signal produced degradation in the absolute measurement accuracy of the cross polarization data, since this vehicle has a very low cross polarized radar cross section.

Non-uniformity in the target reference surfaces, designated for positioning the target, caused positioning inconsistencies significantly greater than those detected by the instruments used to check the target attitude. As a result, inconsistencies can be found in the data by comparisons of the data plots at points such as 0 and 180 degrees azimuth which are extremely sensitive to target pitch.

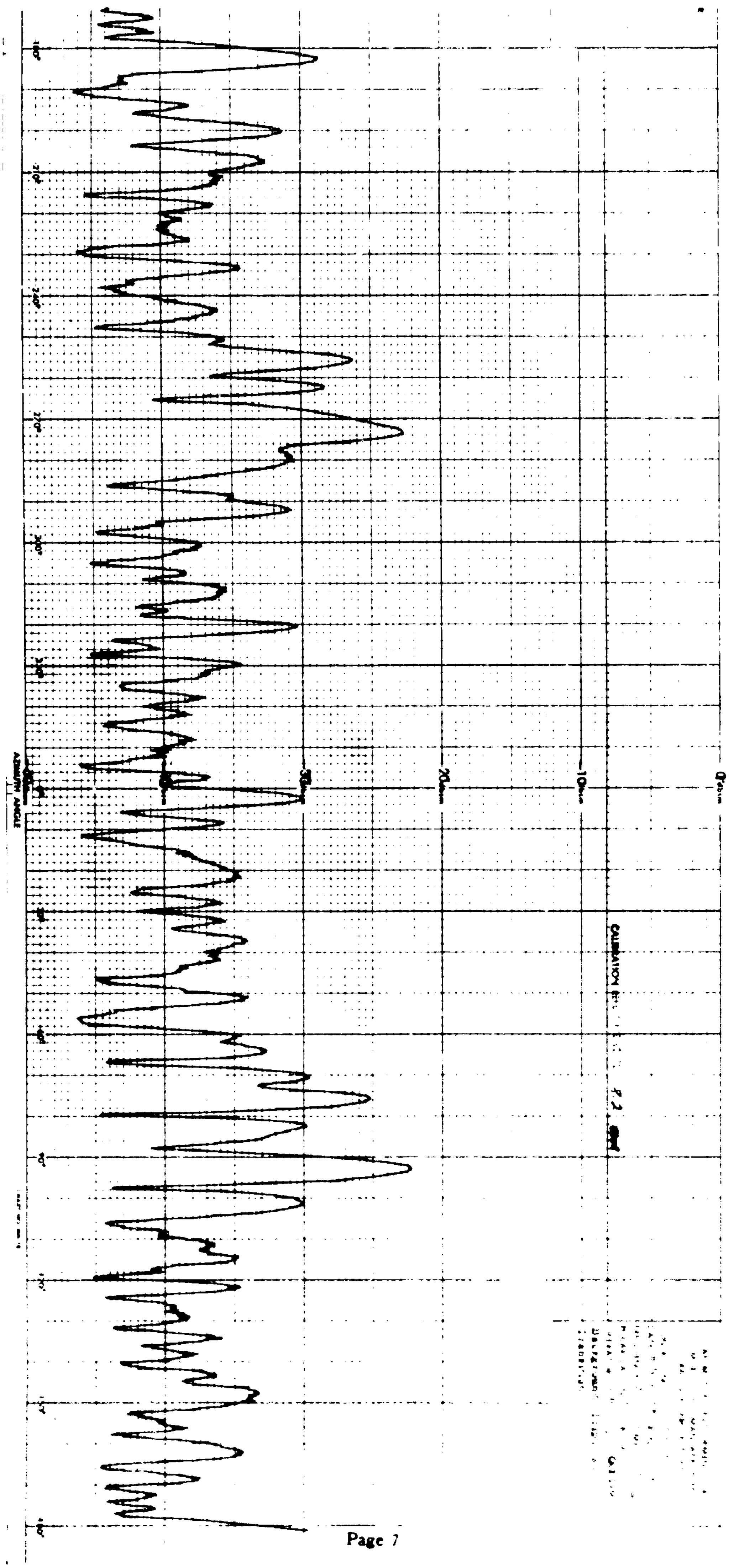
Data

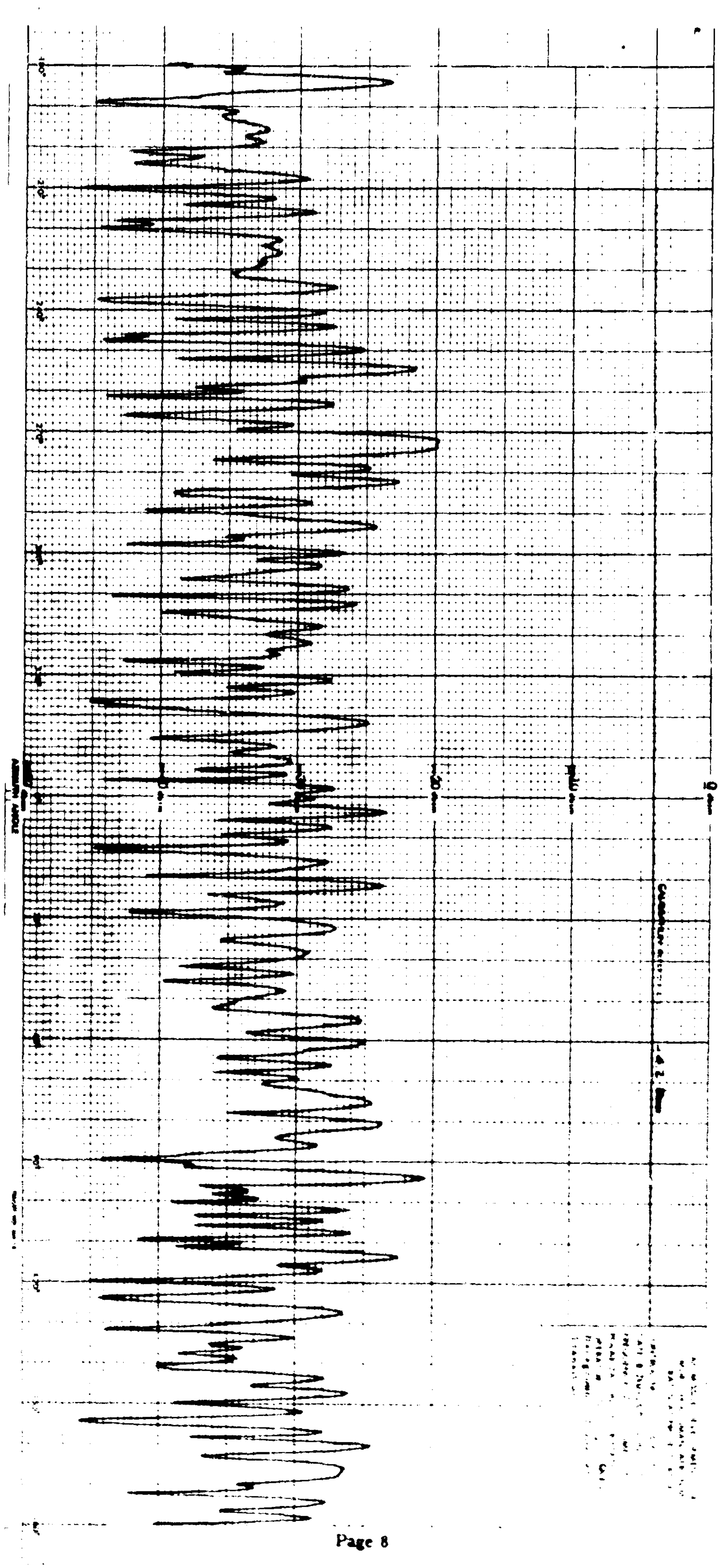
Reproductions of the rectilinear plots are contained in this section and are referenced in the Data Plot Index. Polar plot originals have been forwarded to the designated recipient.

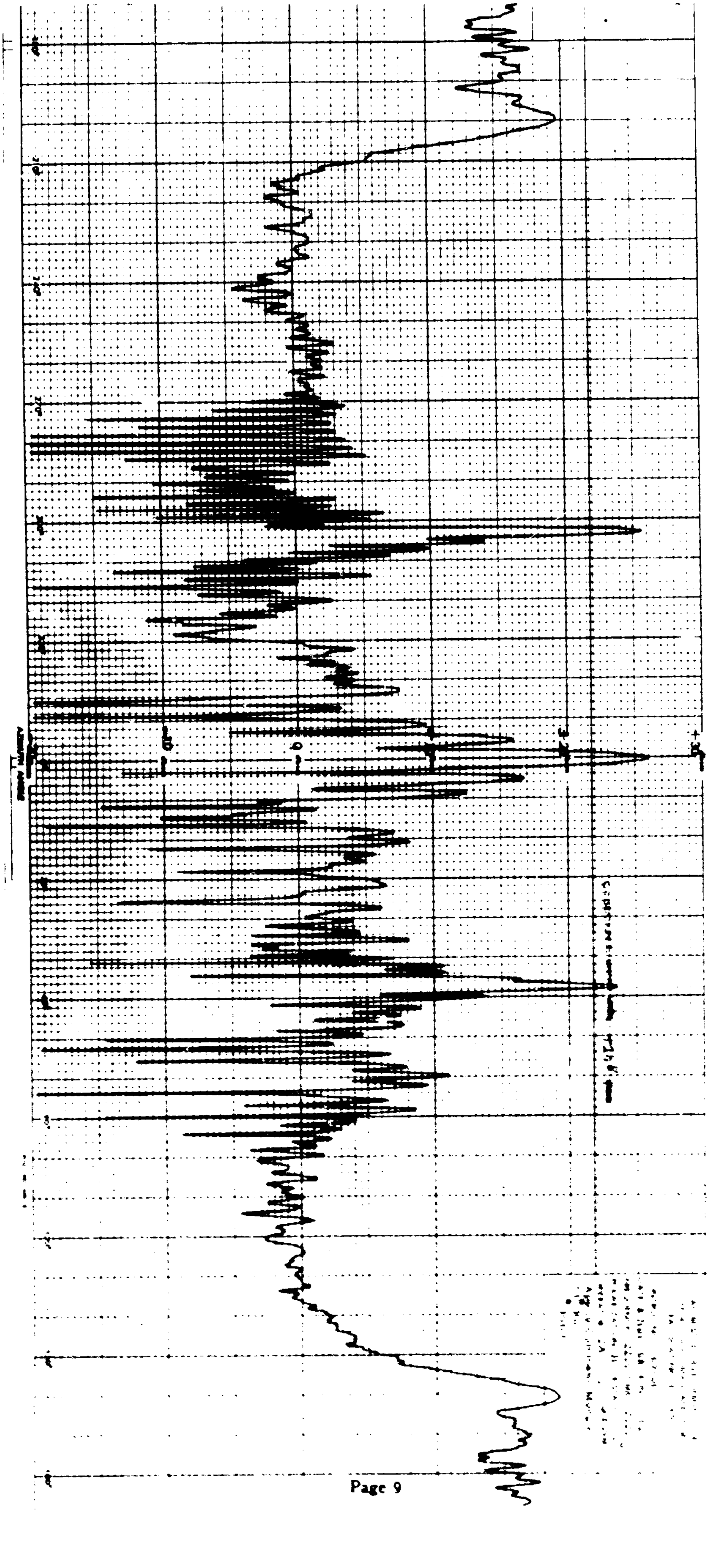
System setup runs are not included in this report. However, all runs documenting the prevailing measurement conditions, as well as the original rectilinear data plots, are logged and filed at MDRT.

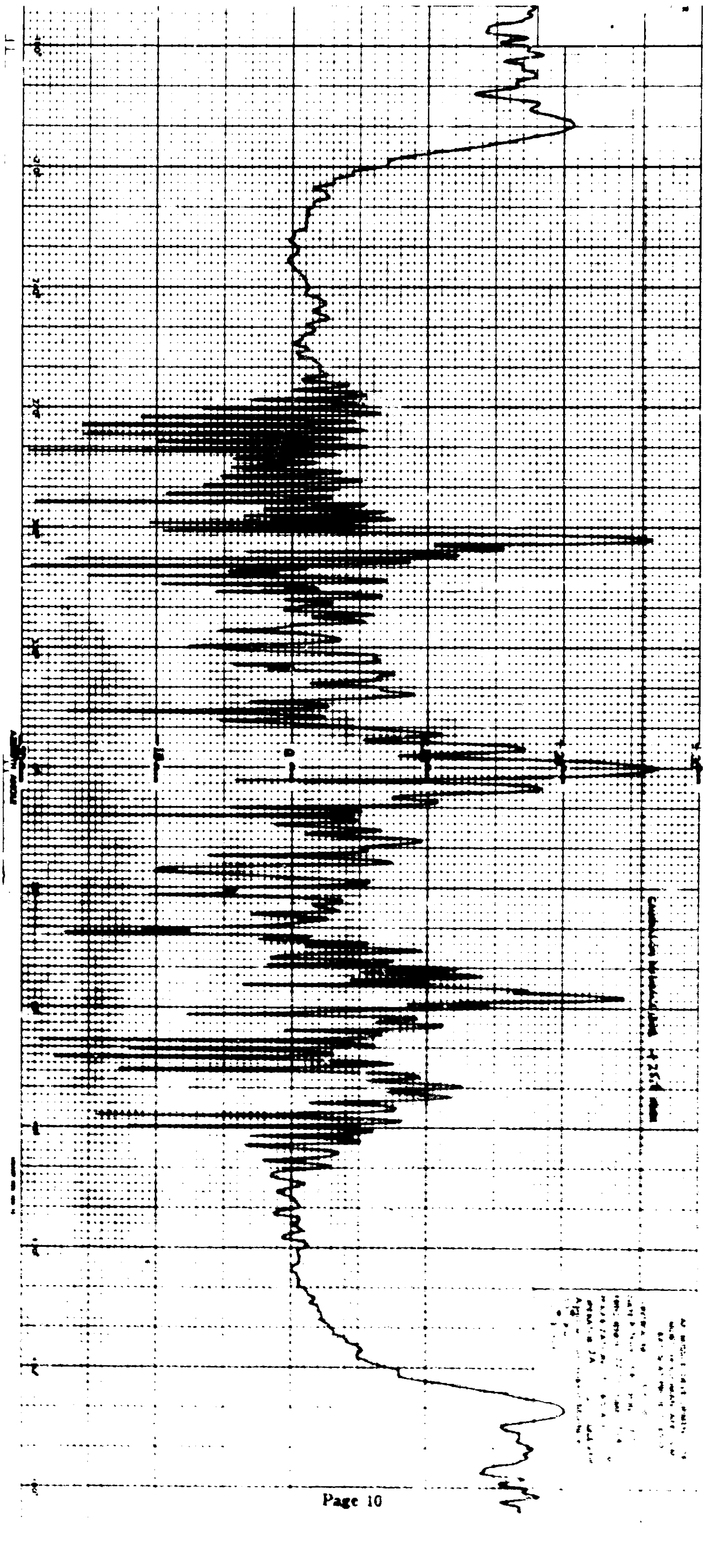
CONTROL NUMBER 69-06 Table I **DATA PLOT INDEX**

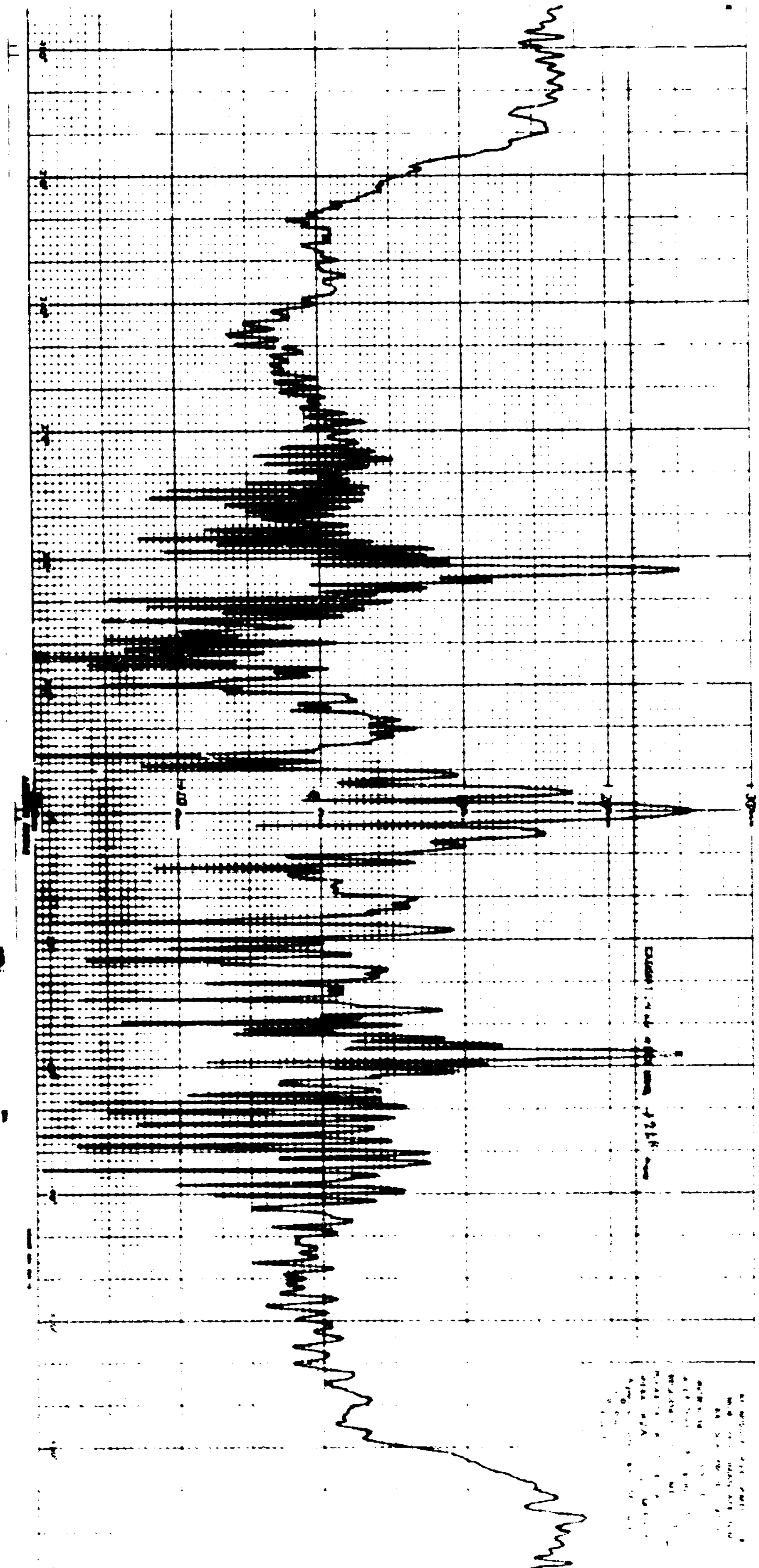
PAGE NO.	RUN	FREQ (MHz)	POLARI-ZATION*	PITCH ANGLE	ROLL ANGLE	TARGET CONFIGURATION AND REMARKS
7	54	2200	H	N/A	N/A	Background, Tripod and Transition
8	55	2200	V	N/A	N/A	Background, Tripod and Transition
9	62	2200	H	0°	53°	Apollo Command Module
10	63	2200	V	0	53	Apollo Command Module
11	60	2200	H	0	106	Apollo Command Module
12	61	2200	V	0	106	Apollo Command Module
13	59	2200	H	0	136	Apollo Command Module
14	58	2200	V	0	136	Apollo Command Module
15	56	2200	H	0	172	Apollo Command Module
16	57	2200	V	0	172	Apollo Command Module
17	18	5690	H	N/A	N/A	Background, Tripod and Transition
18	19	5690	V	N/A	N/A	Background, Tripod and Transition
19	20	5690	Cir.	N/A	N/A	Background, Tripod and Transition
20	16	5690	H	0°	53°	Apollo Command Module
21	15	5690	V	0	53	Apollo Command Module
22	17	5690	Cir.	0	53	Apollo Command Module
23	27	5690	H	0	106	Apollo Command Module
24	28	5690	V	0	106	Apollo Command Module
25	29	5690	Cir.	0	106	Apollo Command Module
26	31	5690	H	0	136	Apollo Command Module
27	32	5690	V	0	136	Apollo Command Module
28	30	5690	Cir.	0	136	Apollo Command Module
29	34	5690	H	0	172	Apollo Command Module
30	33	5690	V	0	172	Apollo Command Module
31	36	5690	Cir.	0	172	Apollo Command Module
32	35	5690	VH	0	172	Apollo Command Module
						* Cir. : XMIT - RC
						REC - LC
						VH : XMIT V
						REC H

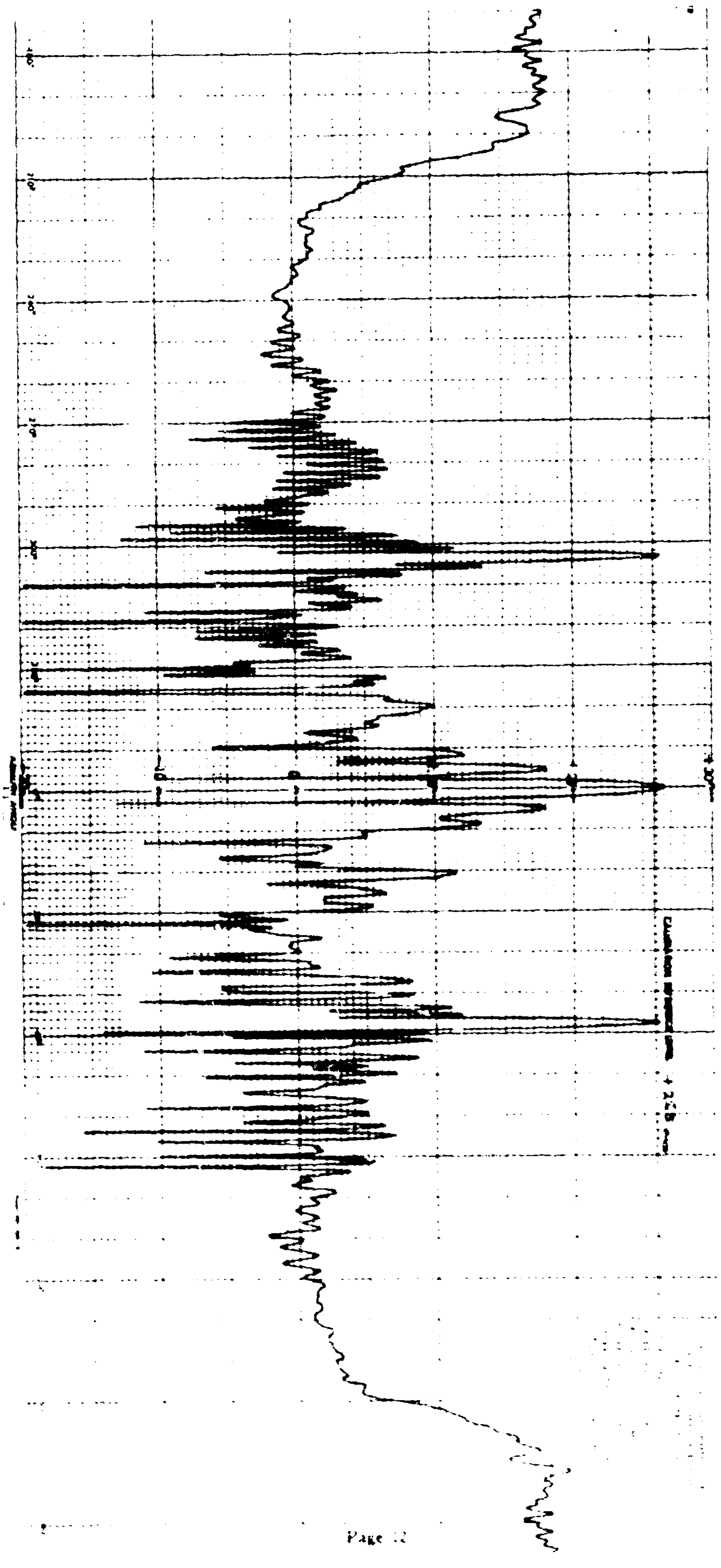

AZIMUTH ANGLE
CALIBRATION
10dbsm
20dbsm
30dbsm

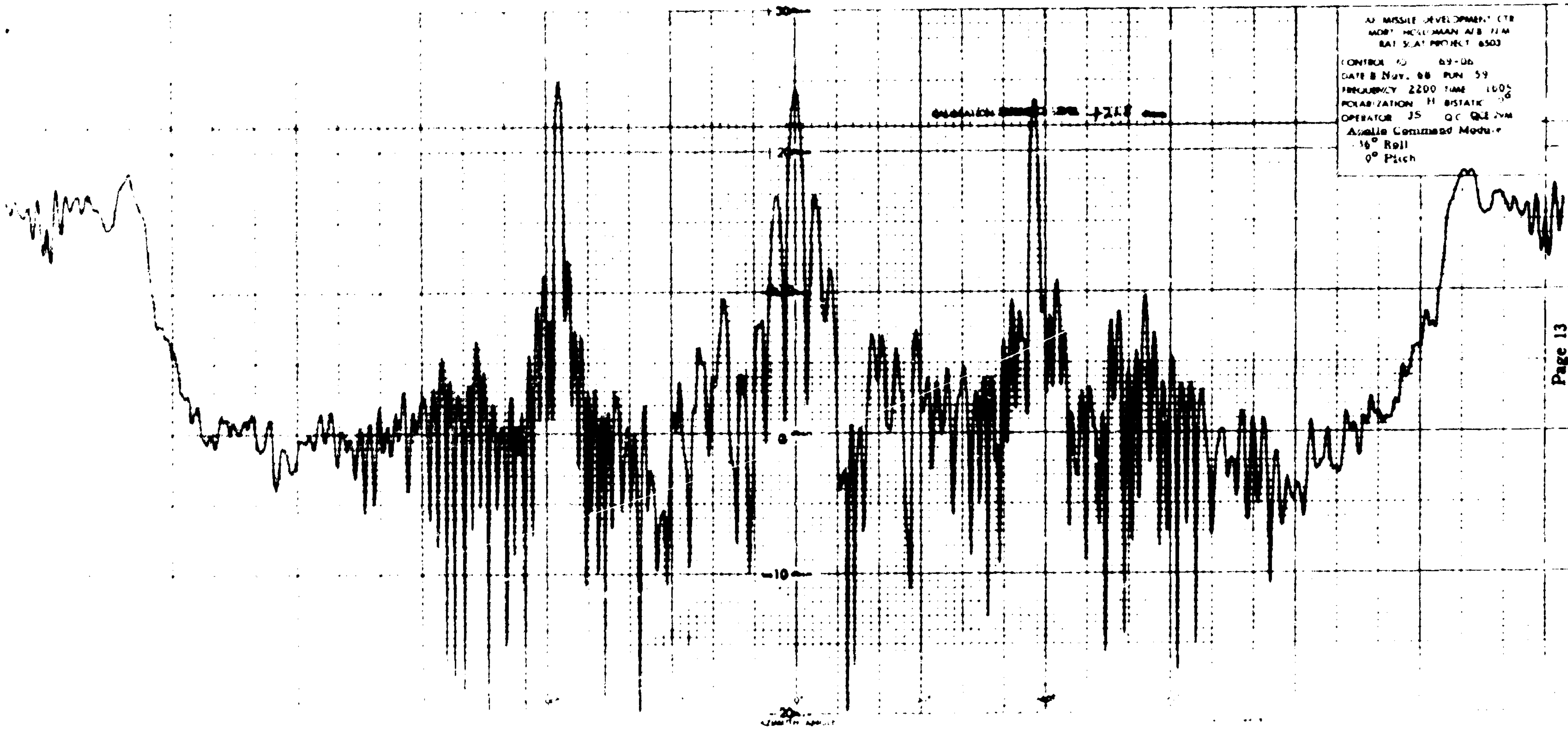








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FREQUENCY 2200 TIME 1605
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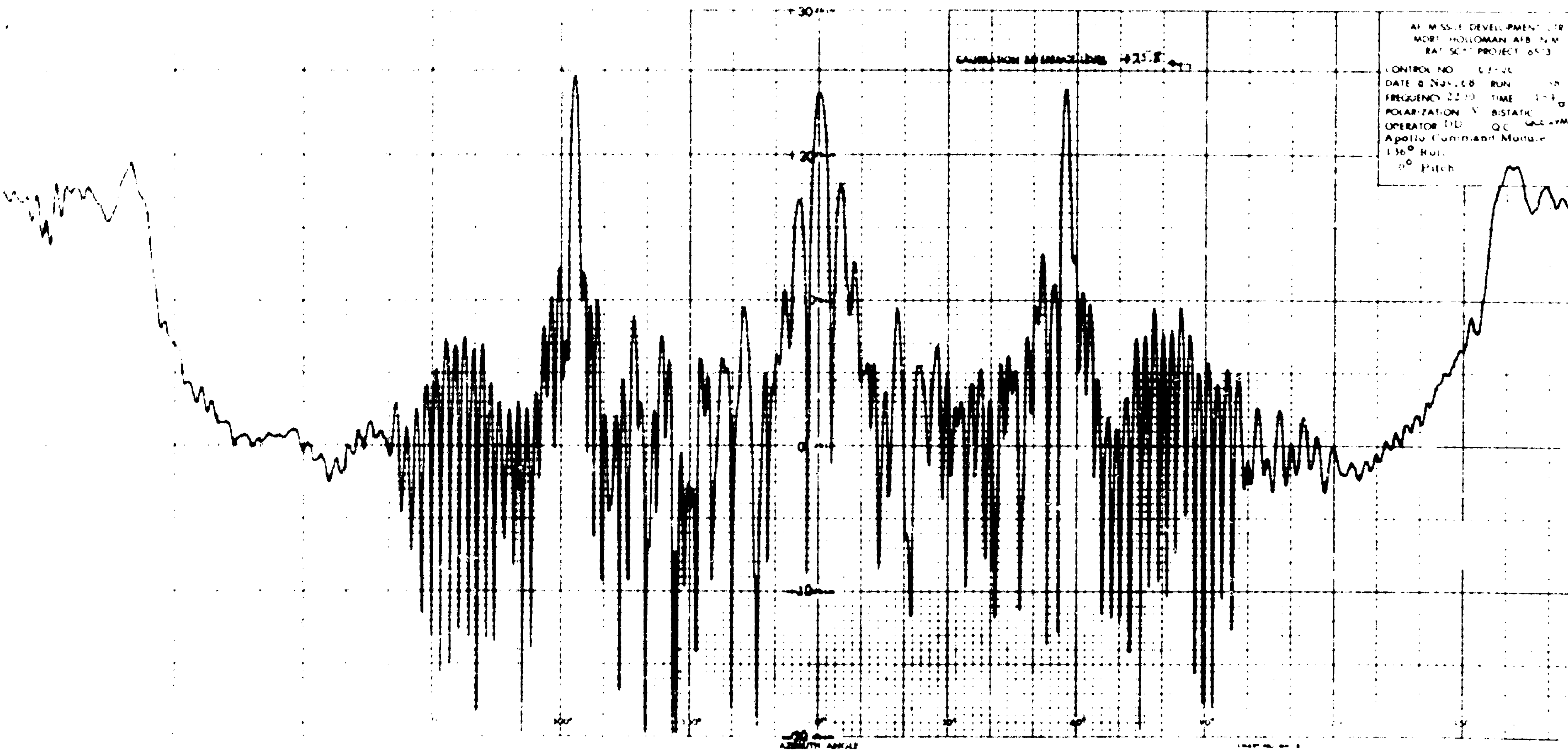
OPERATOR JS QC
Apollo Command Module
36° Roll
0° Pitch
+30
+20
+10
0
-10
-20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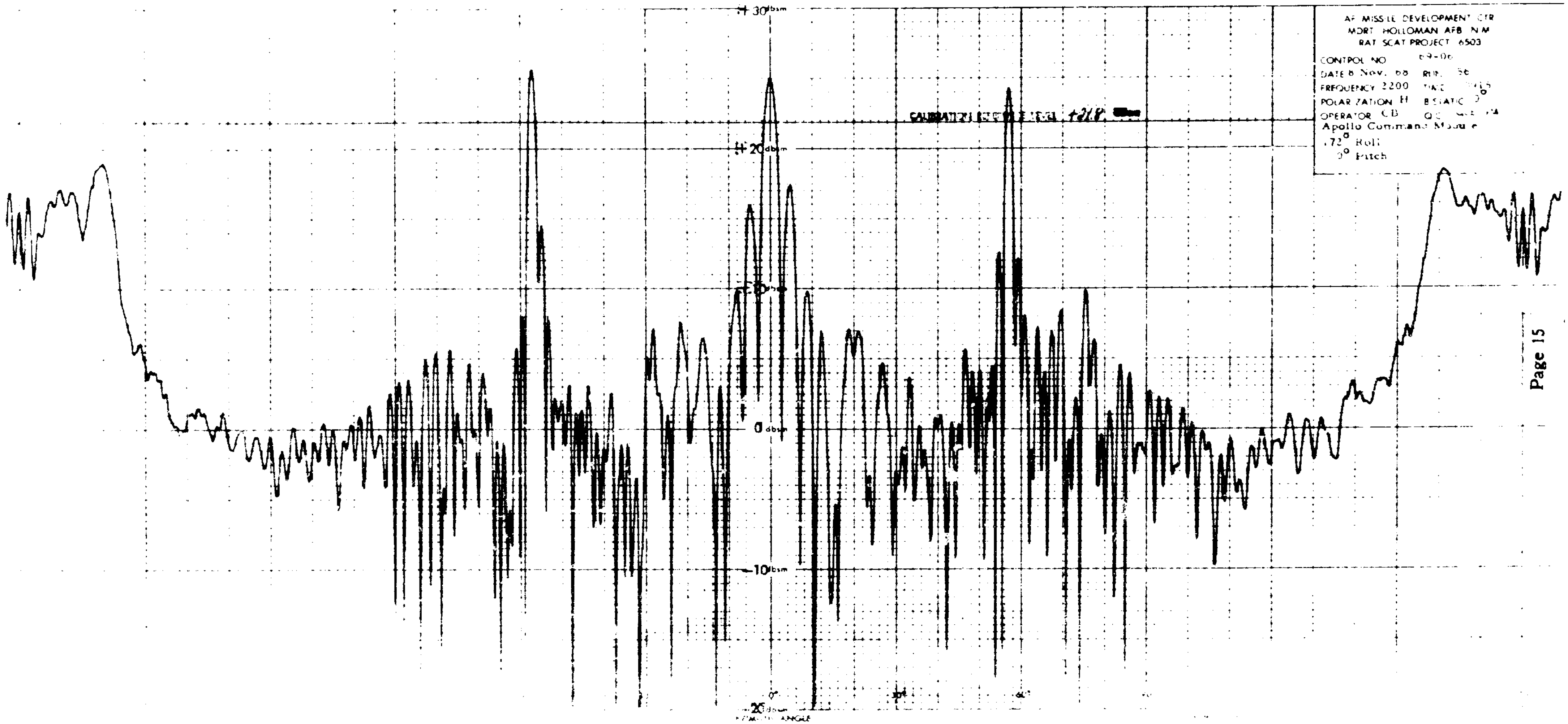
RAT SCAT PROJECT 6513
CONTROL NO
DATE 8 Nov 68 RUN
FREQUENCY 2200 TIME
POLARIZATION V BISTATIC
OPERATOR DD QC
Apollo Command Module
136° Roll
0° Pitch
+30
+20
0
-10
-20
AZIMUTH ANGLE
180°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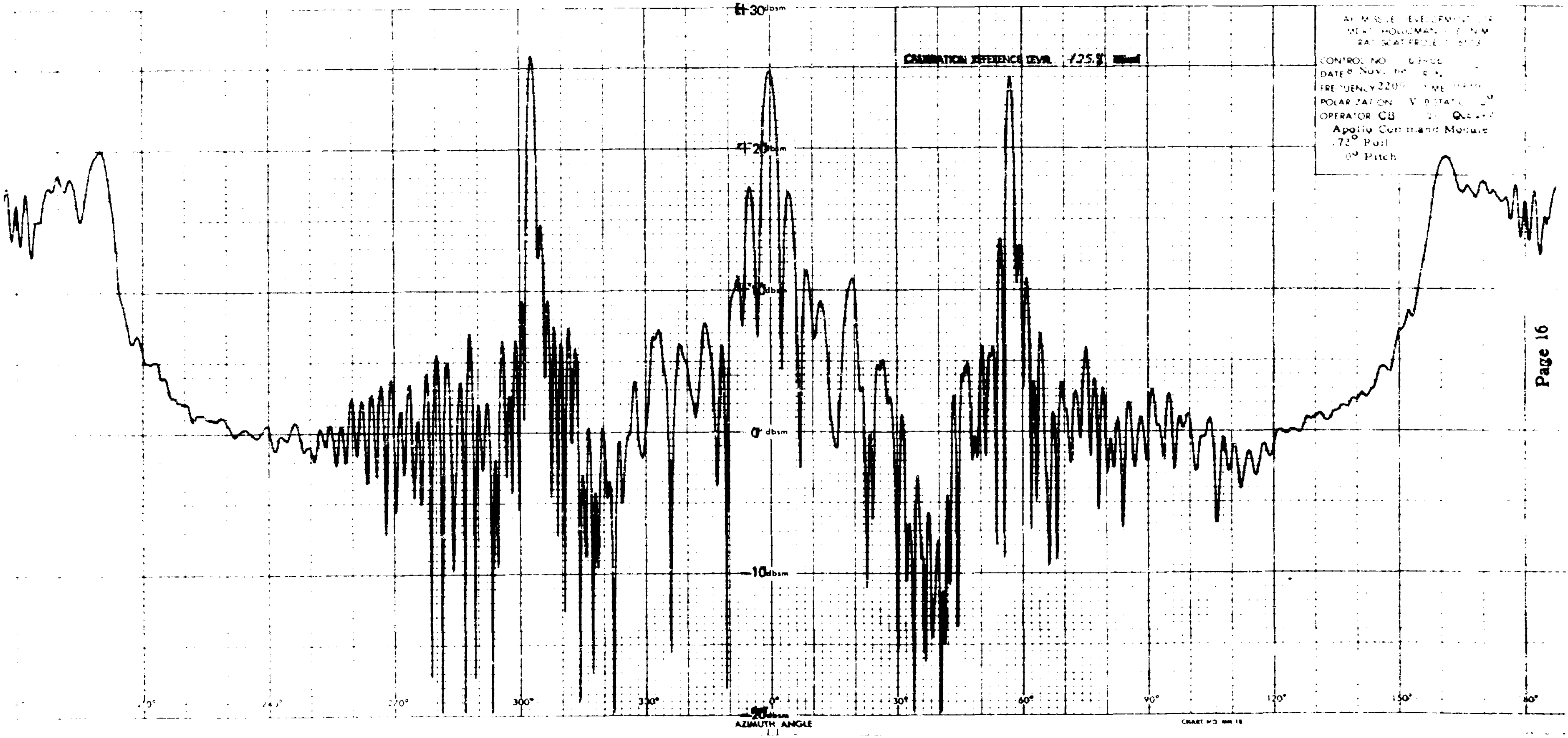
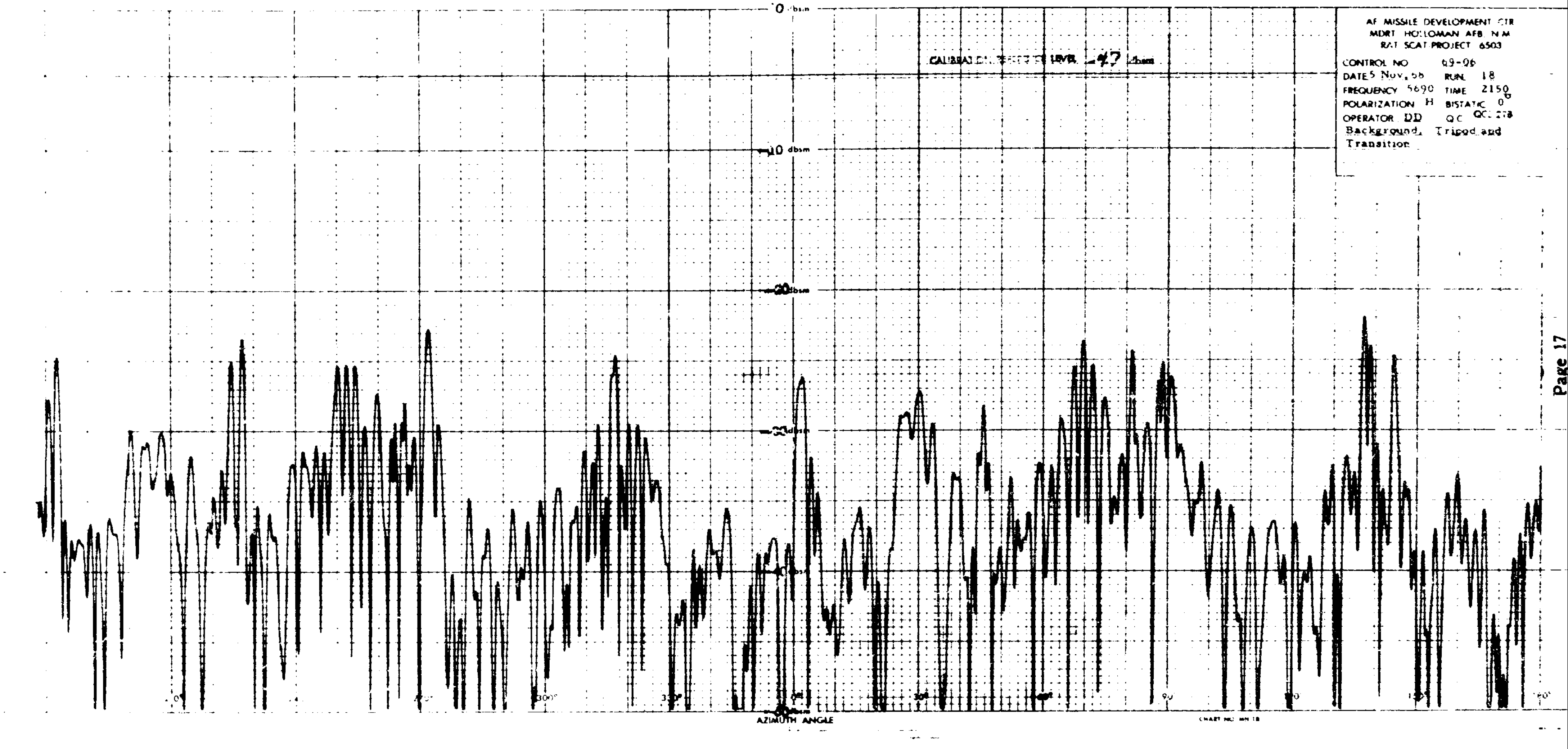
RAT SCAT PROJECT 6503
CONTROL NO 69-06
DATE 8 Nov. 68 RUN 56
FREQUENCY 2200
POLARIZATION H BISTATIC
OPERATOR CB
Apollo Command Module
172° Roll
0° Pitch
CALIBRATION
+30 dbsm
+20 dbsm
10 dbsm
0 dbsm
-10 dbsm
-20 dbsm
AZIMUTH ANGLE


CALIBRATION REFERENCE LEVEL 125.5
Apollo Command Module
72° Roll
0° Pitch
+30 dbsm
+20 dbsm
+10 dbsm
0 dbsm
−10 dbsm
−20 dbsm
AZIMUTH ANGLE
270°
300°
330°
0°
30°
60°
90°
120°
150°
180°



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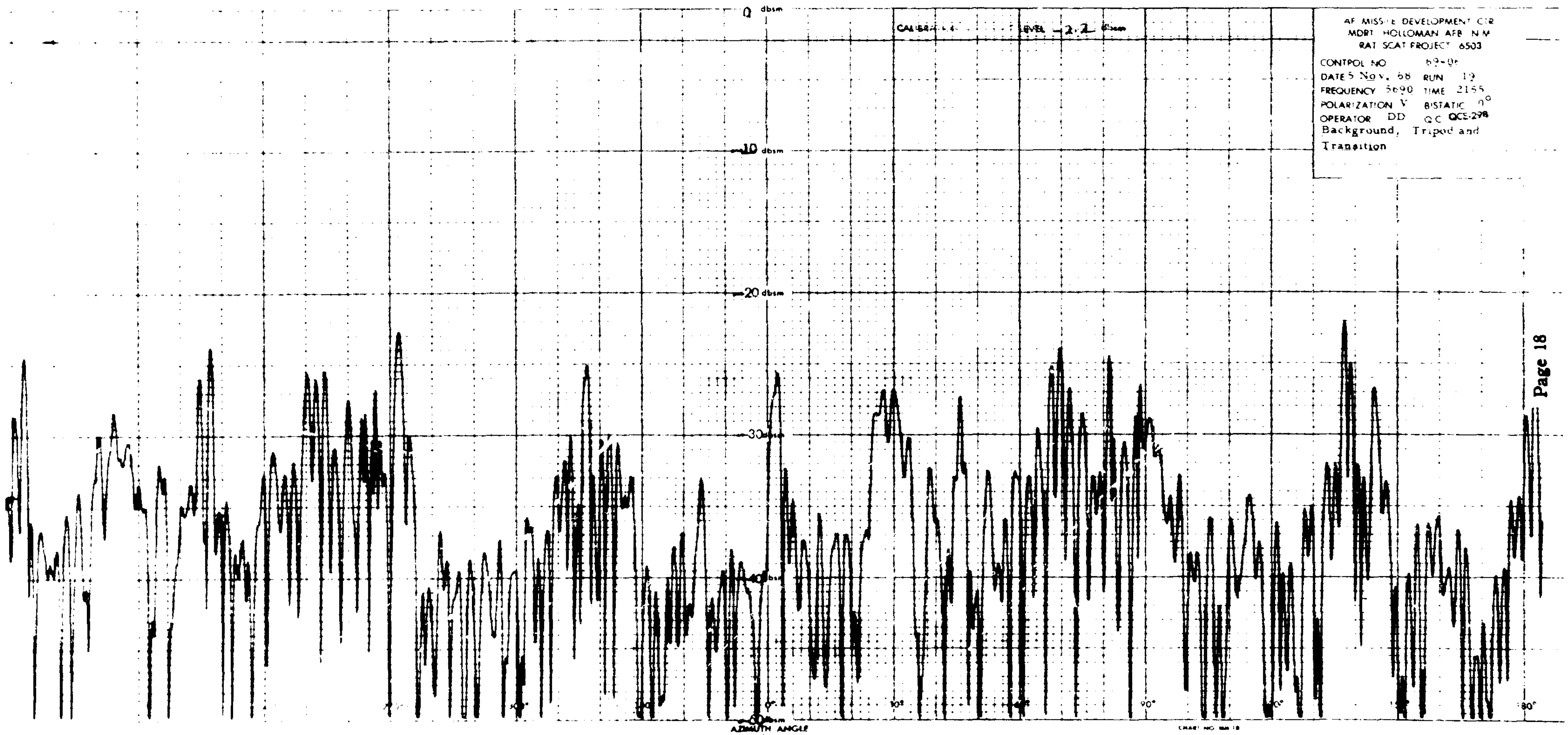
MDRT HOLLOMAN AFB N M
RAT SCAT PROJECT 6503
CONTROL NO 69-06
DATE 5 Nov, 56 RUN 18
FREQUENCY 5690 TIME 2150
POLARIZATION H BISTATIC 0
OPERATOR DD
Background, Tripod and Transition
LEVEL -47 dbsm
0 dbsm
10 dbsm
20 dbsm
AZIMUTH ANGLE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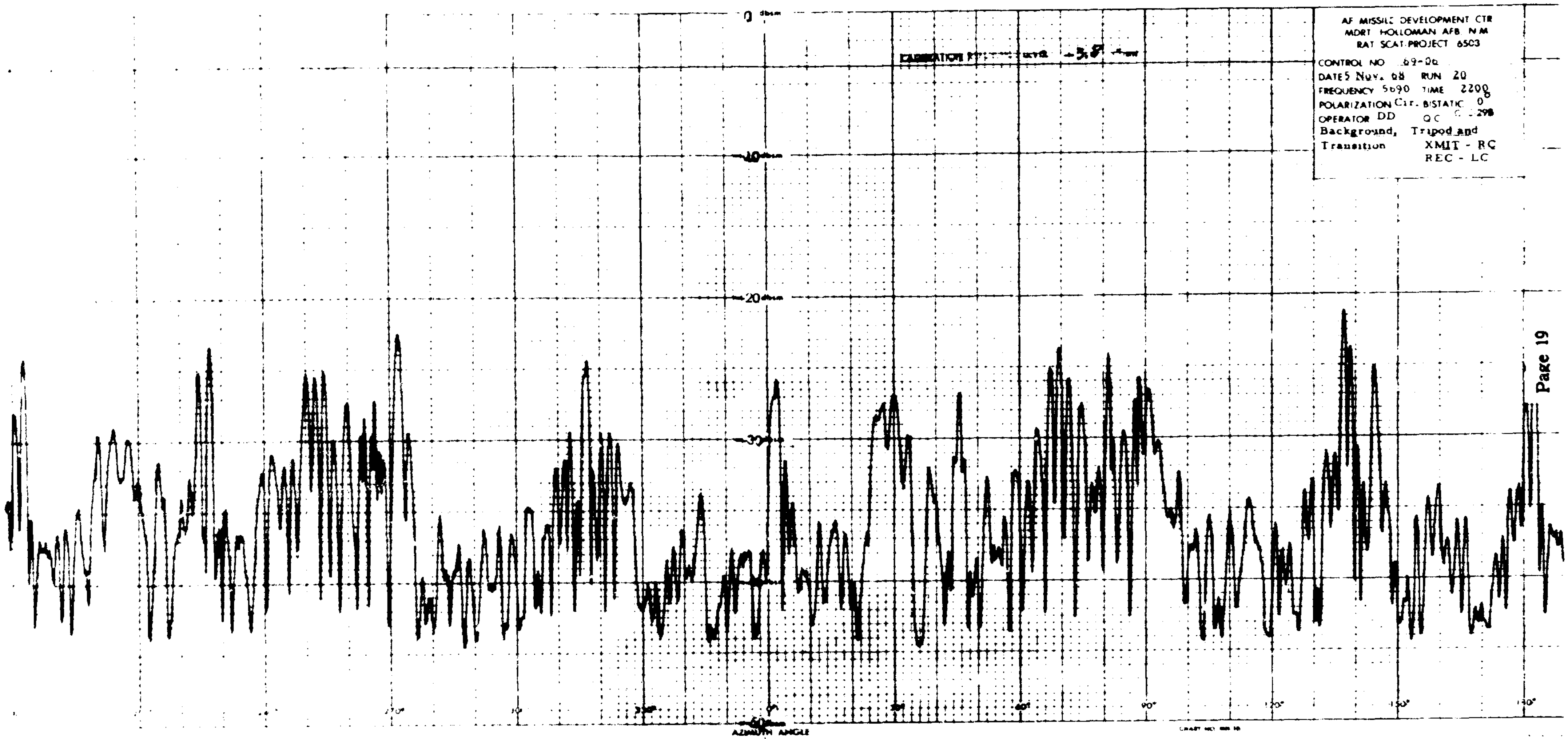
CONTROL NO 69-06
DATE 5 Nov. 68 RUN 19
FREQUENCY 5690 TIME 2155
POLARIZATION V BISTATIC 0°
OPERATOR DD QC QCS-298
Background, Tripod and Transition
CALIBRA
LEVEL -2.2 dbsm
0 dbsm
10 dbsm
20 dbsm
30 dbsm
40 dbsm
50 dbsm
AZIMUTH ANGLE
90°
180°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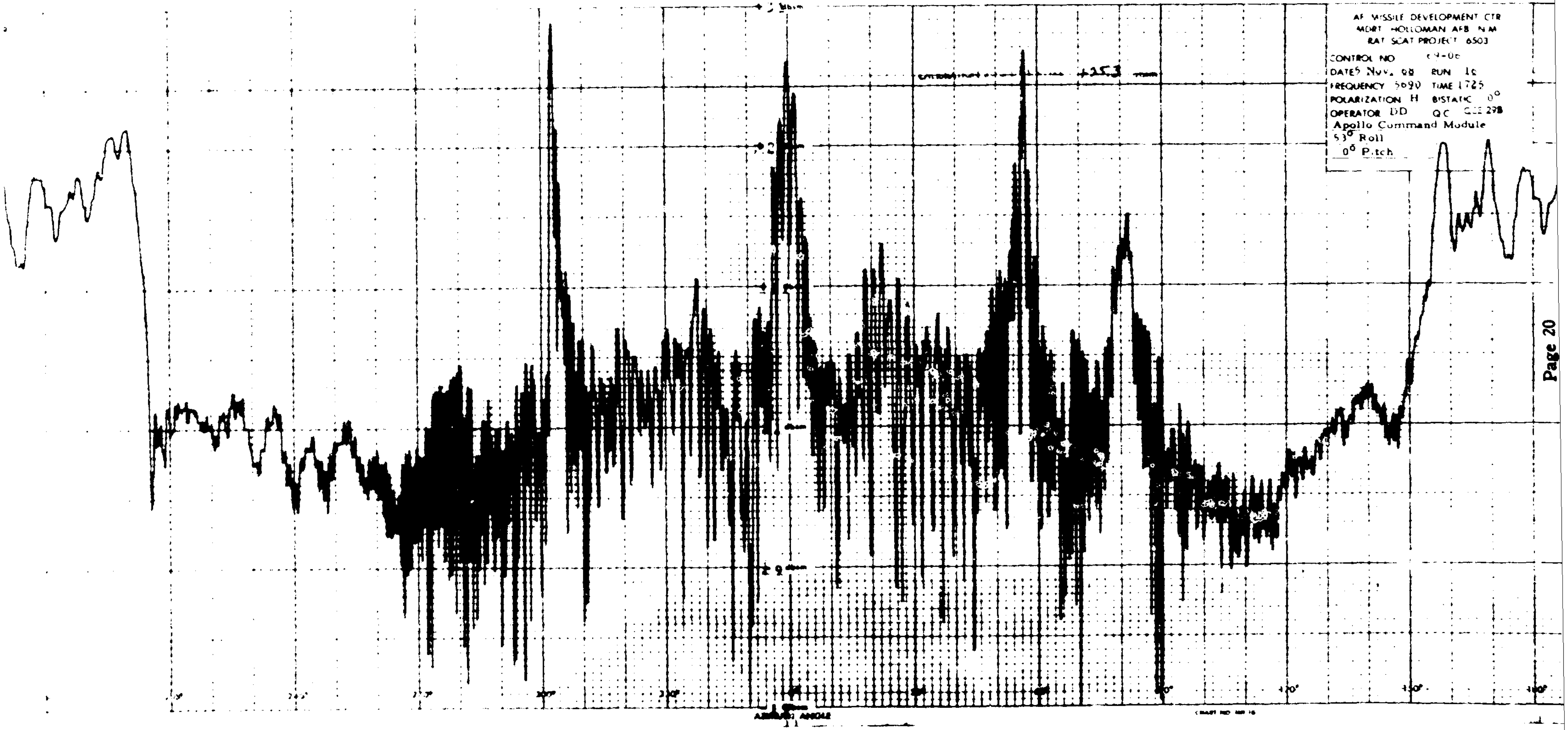
DATE 5 Nov. 68 RUN 20
FREQUENCY 5690 TIME 2200
POLARIZATION Cir. BISTATIC 0°
OPERATOR DD QC
Background, Tripod and Transition
XMIT - RC
REC - LC
0 dbsm
-10 dbsm
-20 dbsm
-30
-40 dbsm
AZIMUTH ANGLE
270°
330°
0°
30°
60°
90°
120°
150°
180°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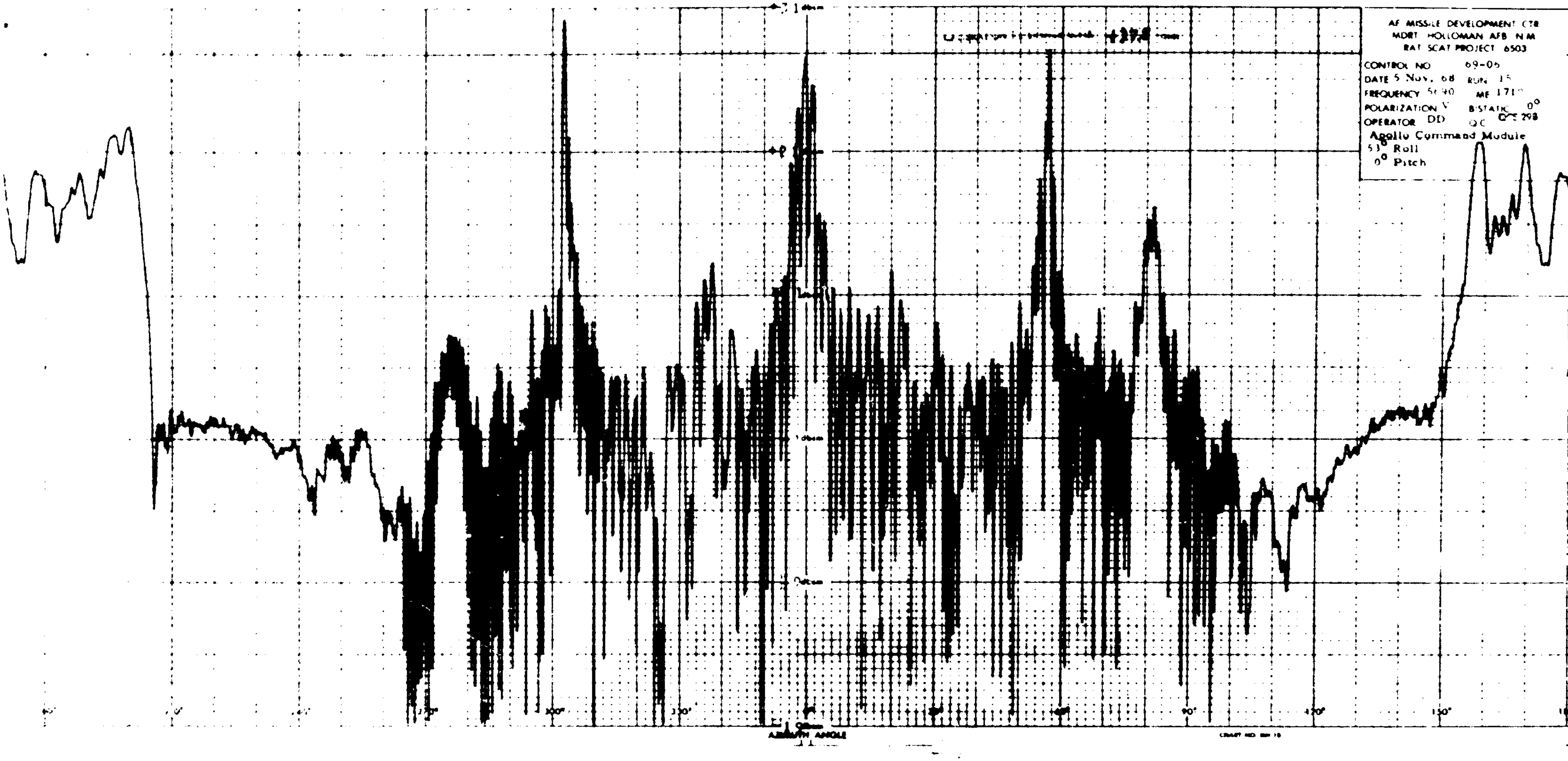
RAT SCAT PROJECT 6503
CONTROL NO
DATES Nov. 68 RUN 16
FREQUENCY 5690 TIME 1725
POLARIZATION H BISTATIC 0°
OPERATOR DD QC
Apollo Command Module
53° Roll
0° Pitch
+25.3
AZIMUTH ANGLE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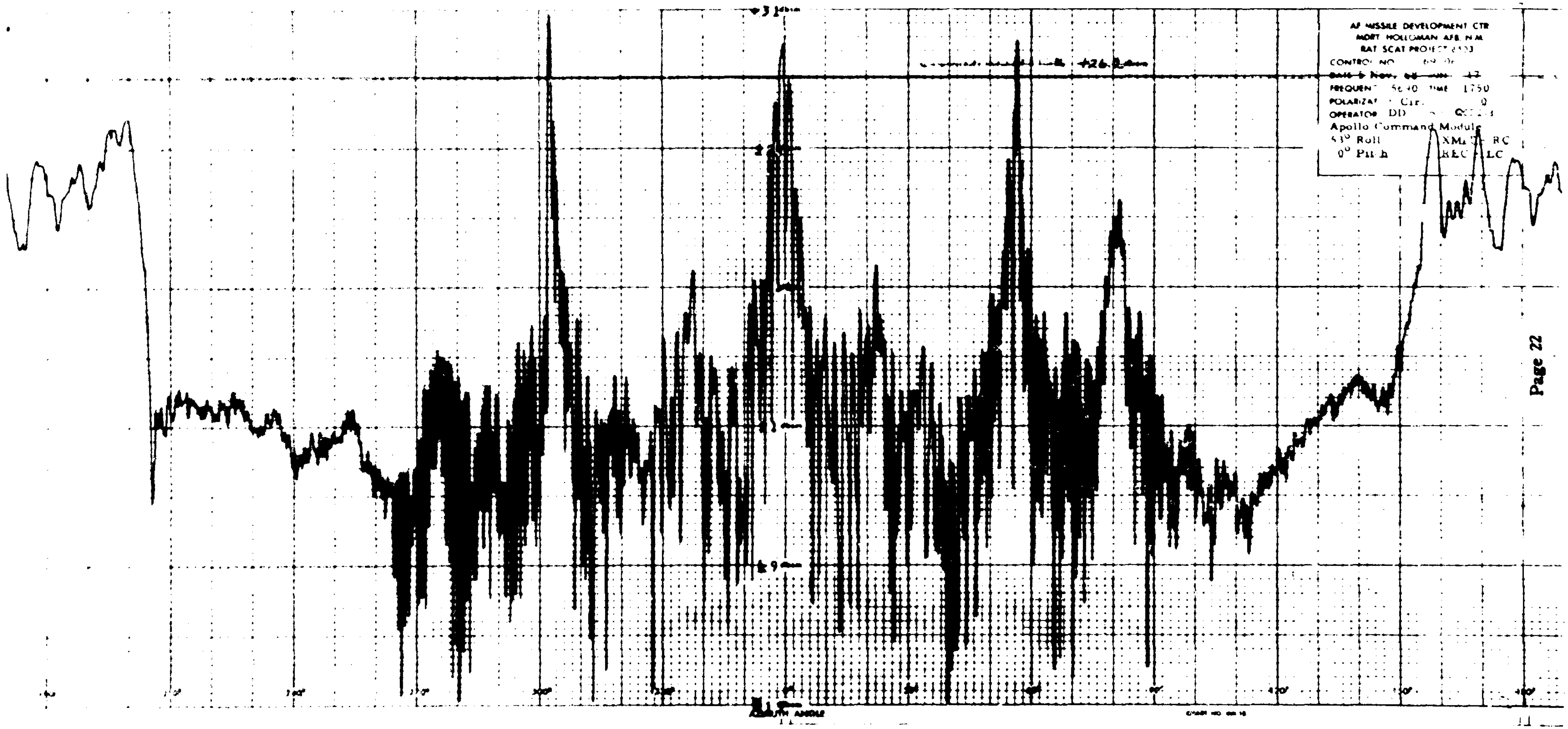
CONTROL NO 69-05
DATE 5 Nov, 68 RUN 15
FREQUENCY 5690 ME 171°
POLARIZATION V BISTATIC 0°
OPERATOR DD QC
Apollo Command Module
53° Roll
0° Pitch
AZIMUTH ANGLE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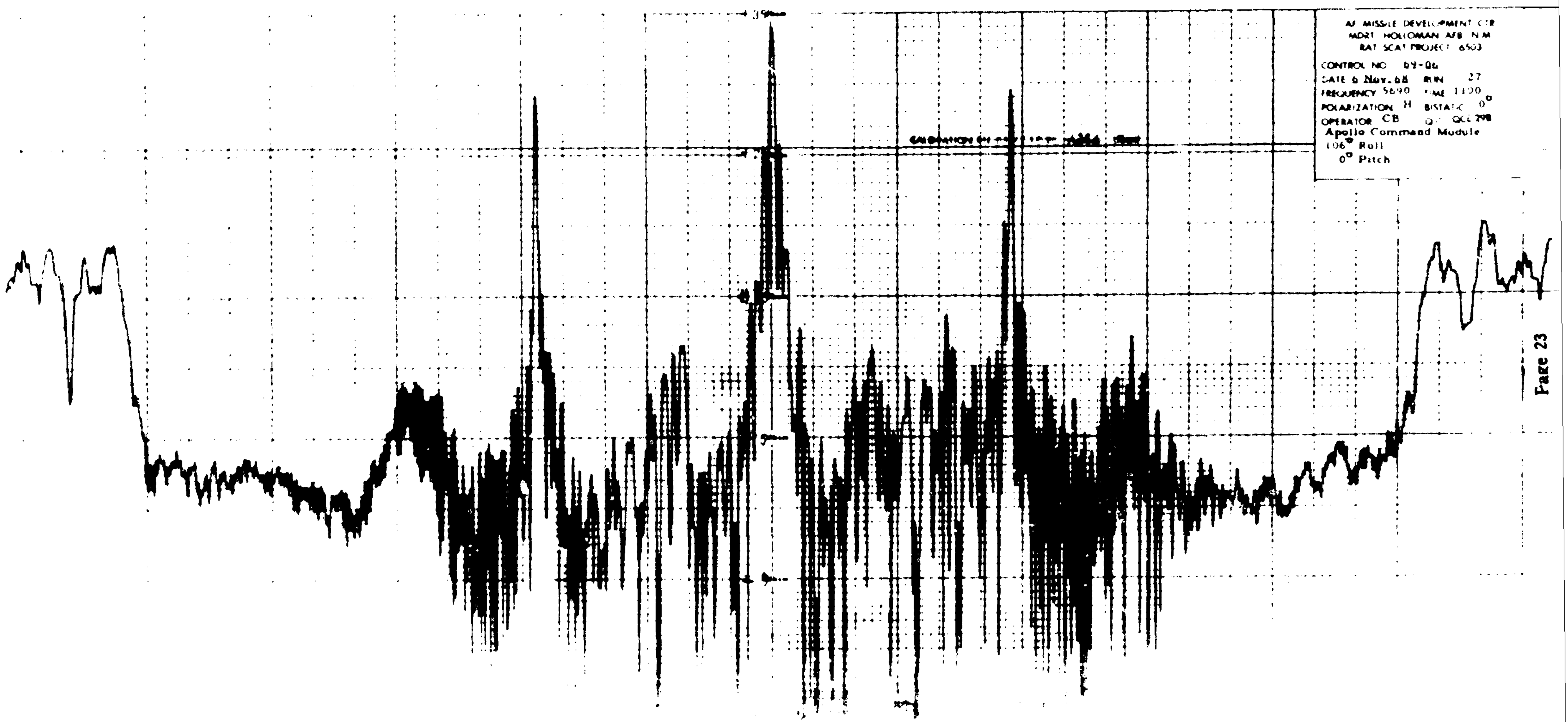
POLARIZATION Cir. 0
OPERATOR DD
Apollo Command Module
0° Pitch
AZIMUTH ANGLE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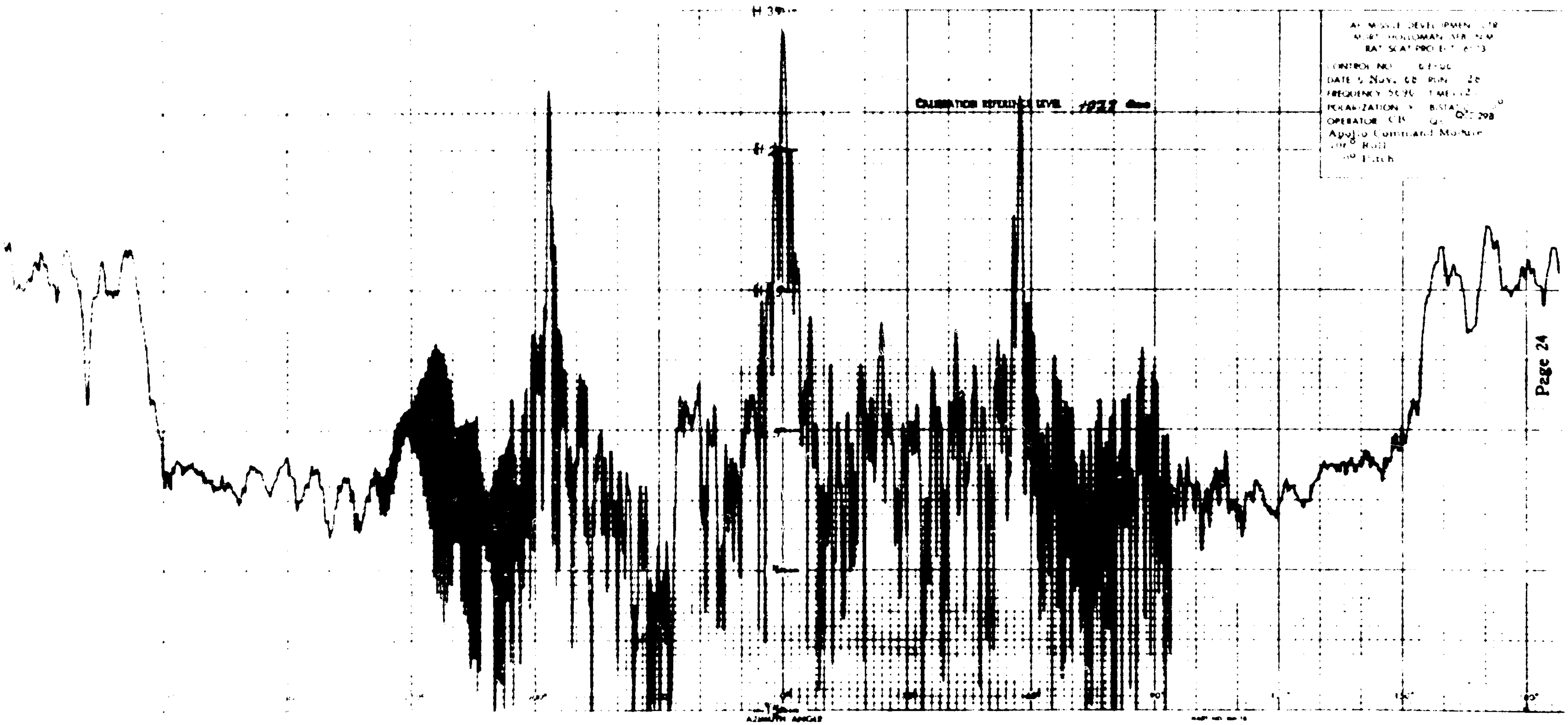
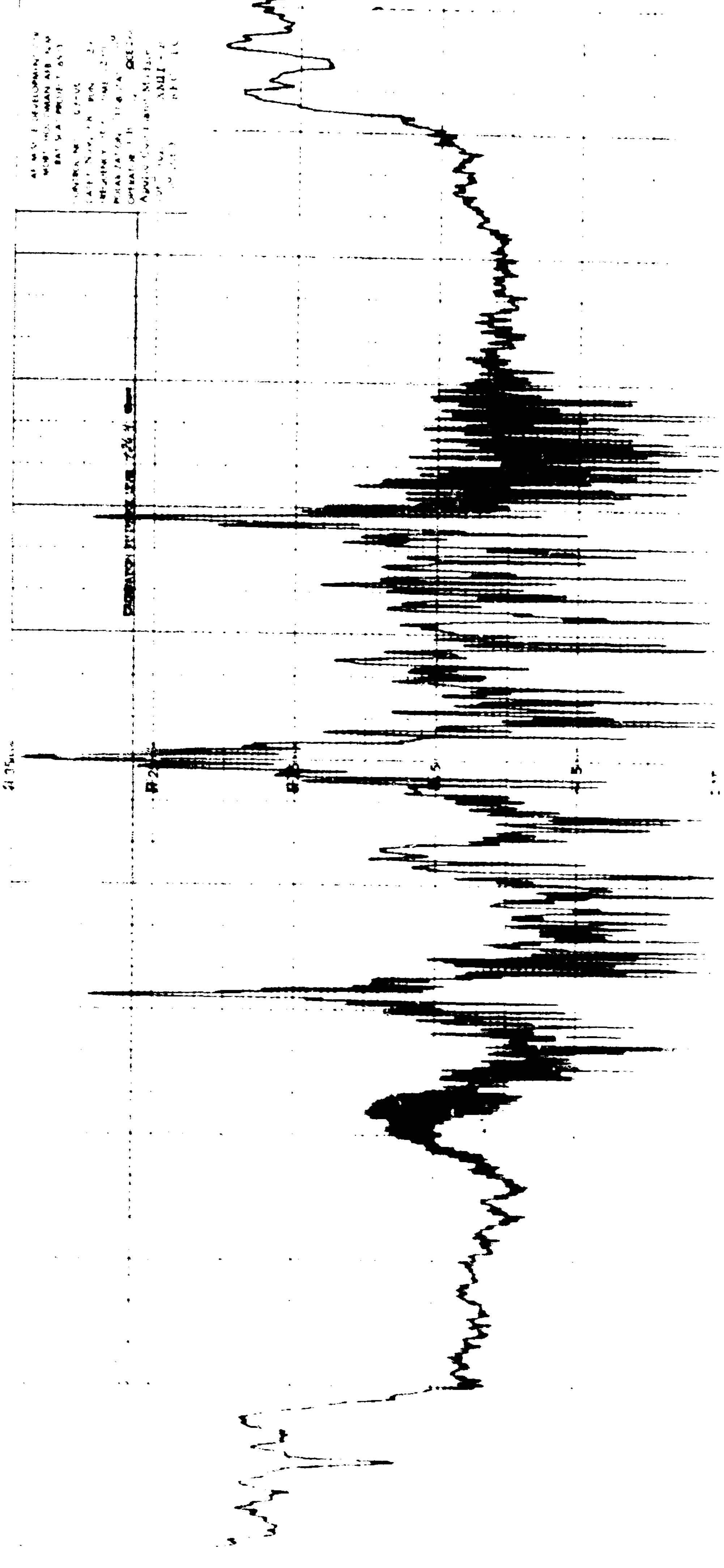
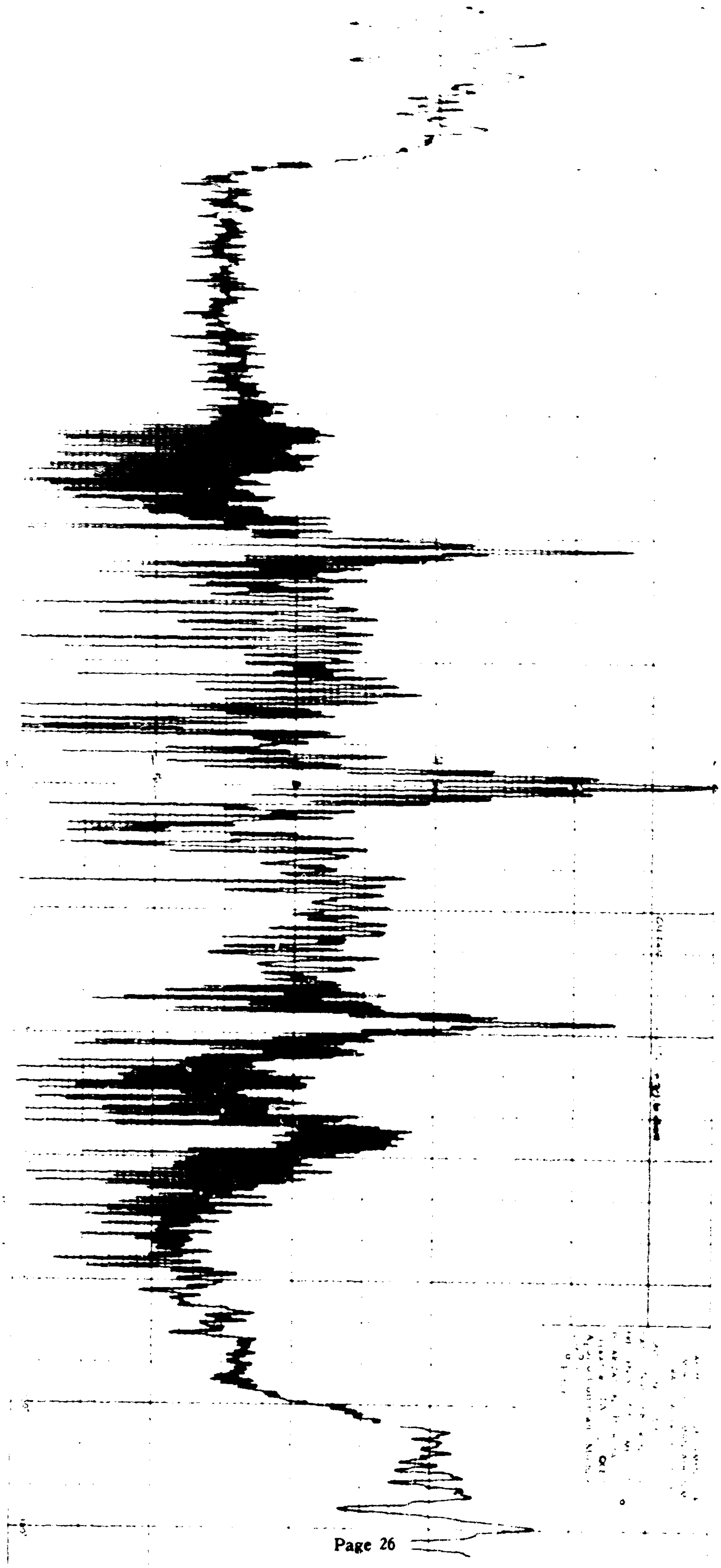
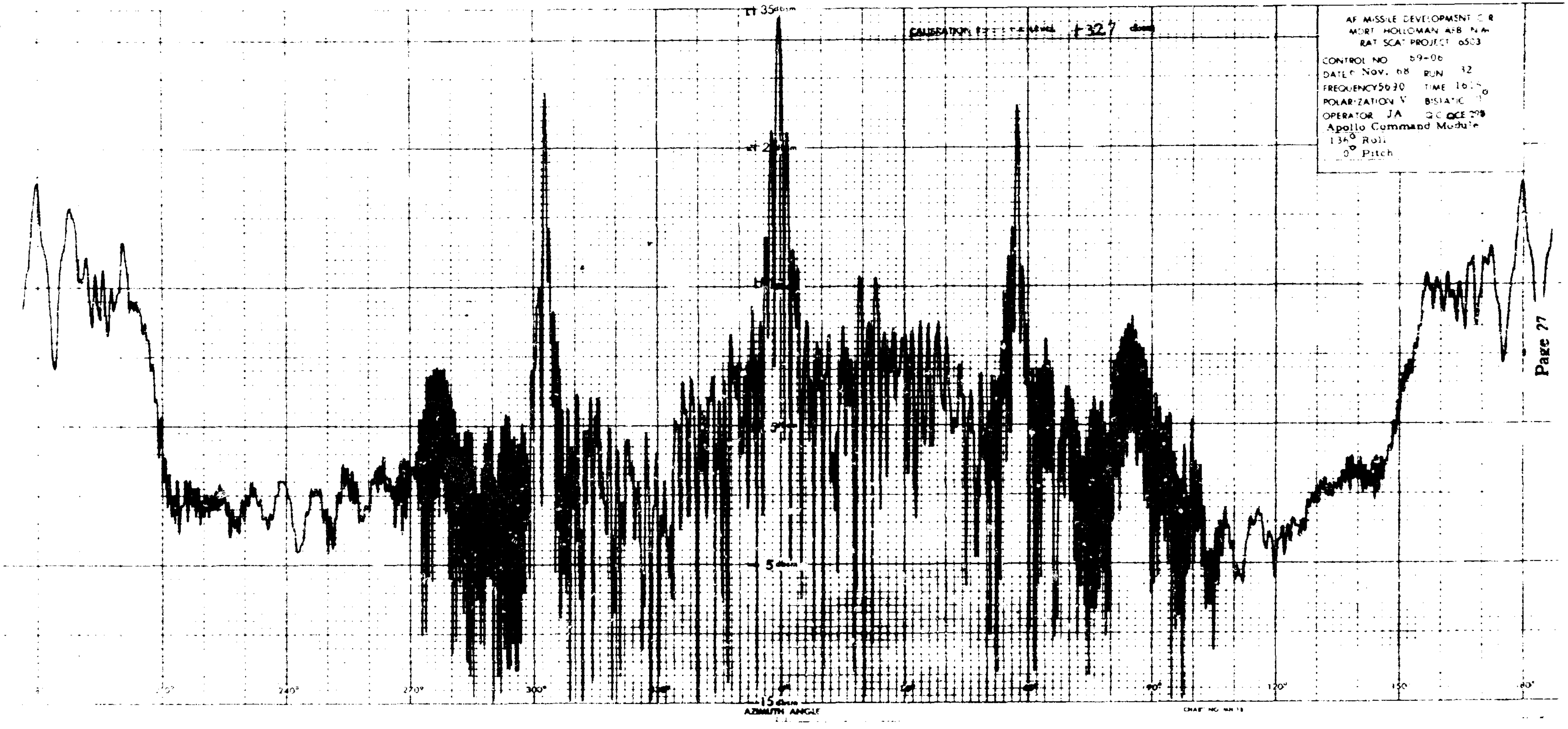
DATE 6 Nov. 68 RUN 27
FREQUENCY 5690 TIME 1130
POLARIZATION H BISTATIC 0°
OPERATOR CB QCE 298
Apollo Command Module
106° Roll
0° Pitch
CALIBRATION



DATE
FREQUENCY
POLARIZATION
OPERATOR
Apollo Command Module
Roll
Pitch
CALIBRATION REFERENCE LEVEL
AZIMUTH ANGLE



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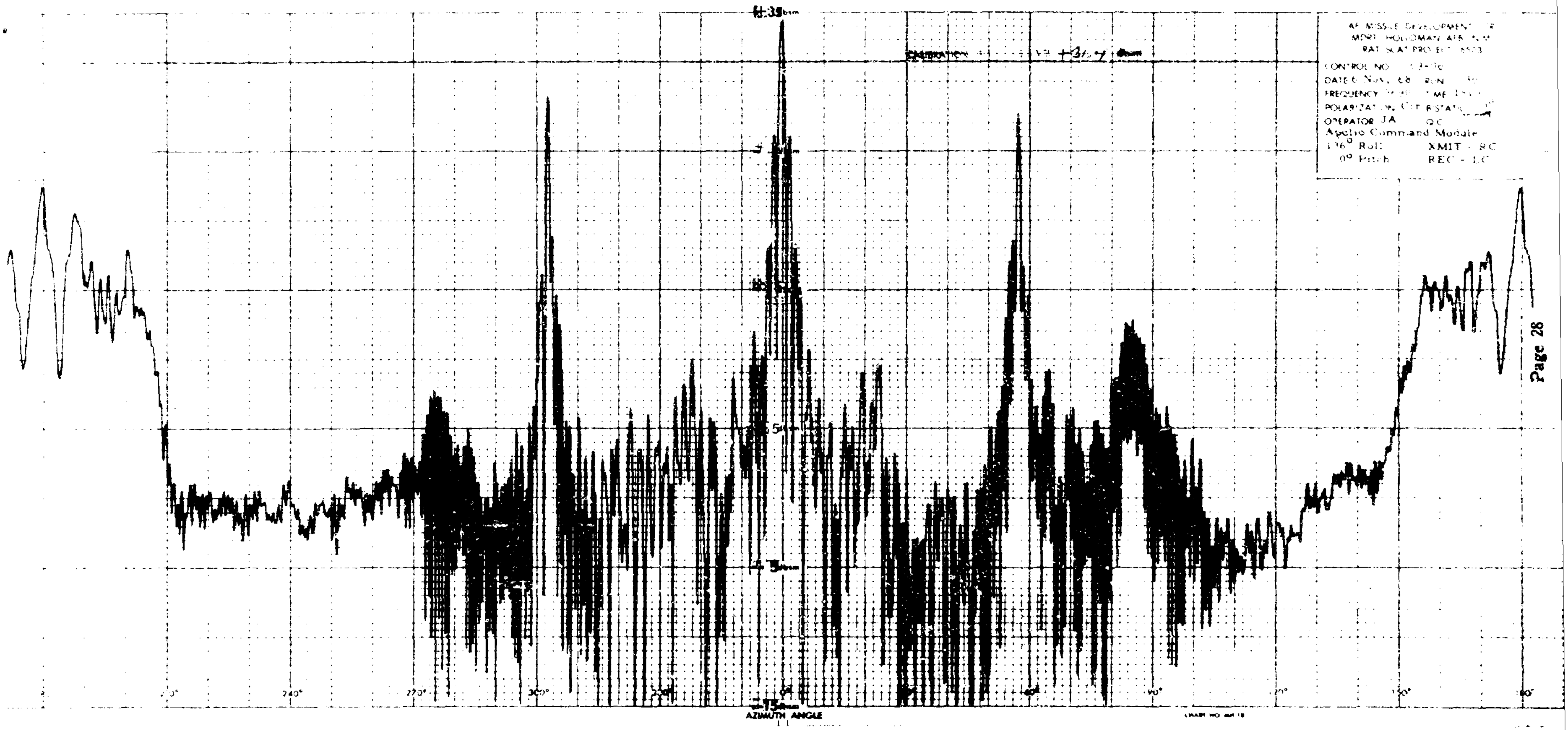
HOLLOMAN AFB N M
RAT SCAT PROJECT 6503
CONTROL NO 69-06
DATE Nov. 68 RUN 32
FREQUENCY 5630 TIME 16
POLARIZATION V BISTATIC
OPERATOR JA
Apollo Command Module
136° Roll
0° Pitch
CALIBRATION +32.7 dbsm
35 dbsm
25
5 dbsm
15 dbsm
240°
270°
300°
90°
120°
150°
180°
AZIMUTH ANGLE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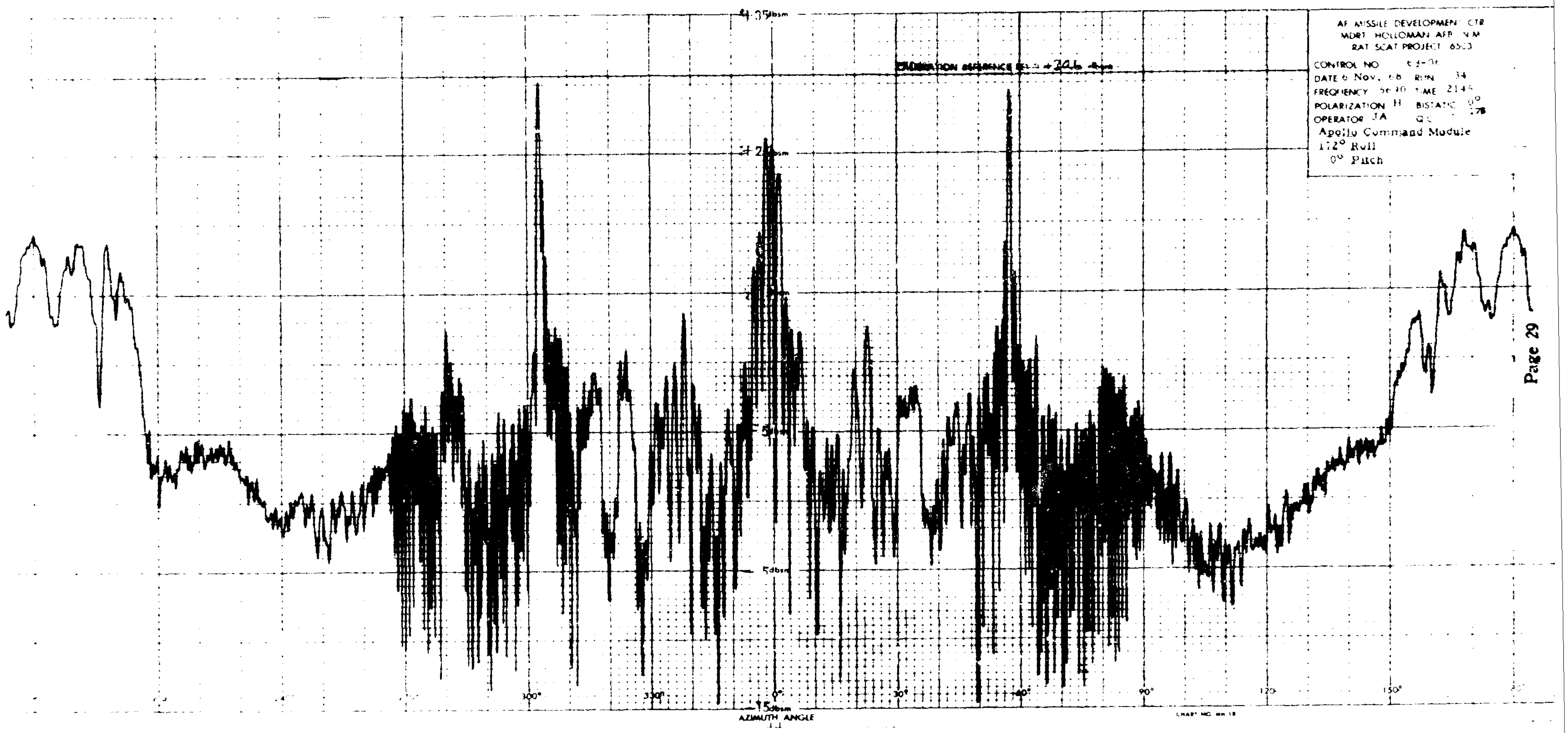
MDRT HOLLOMAN AFB
RAT SCAT PROJECT
CONTROL NO
DATE 6 Nov, 68 RUN
FREQUENCY TIME
POLARIZATION BISTATIC
OPERATOR JA QC
Apollo Command Module
136° Roll XMIT - RC
0° Pitch REC - LC
CALIBRATION
240°
270°
300°
90°
150°
180°
AZIMUTH ANGLE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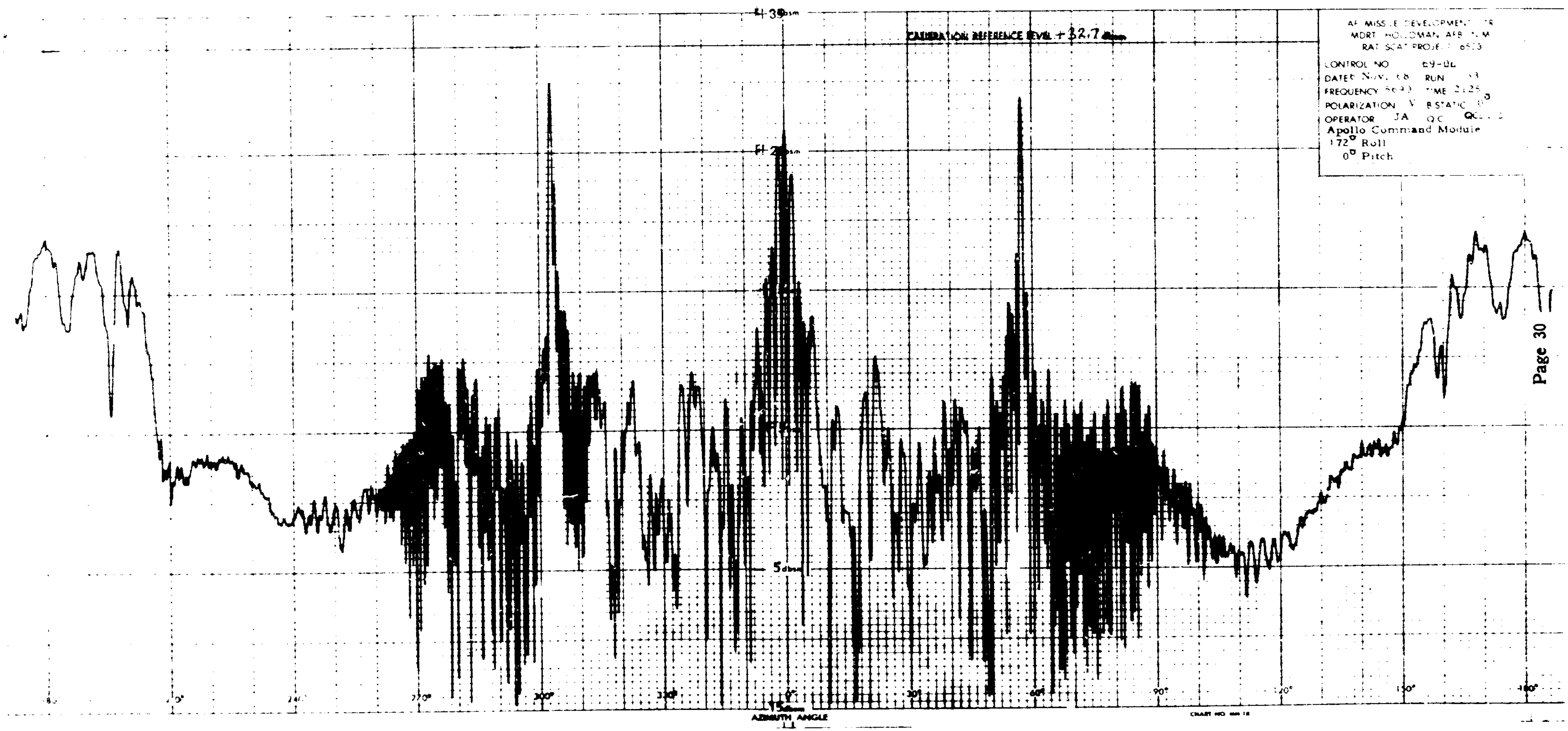
RAT SCAT PROJECT 6503
CONTROL NO 63-06
DATE 6 Nov. 68 RUN 34
FREQUENCY 5630 TIME 2145
POLARIZATION H BISTATIC 0°
OPERATOR JA
Apollo Command Module
172° Roll
0° Pitch
CALIBRATION REFERENCE + 20.6 dbsm
4.35dbsm
+ 2dbsm
5dbsm
15dbsm
AZIMUTH ANGLE
300°
330°
0°
30°
60°
90°
120°
150°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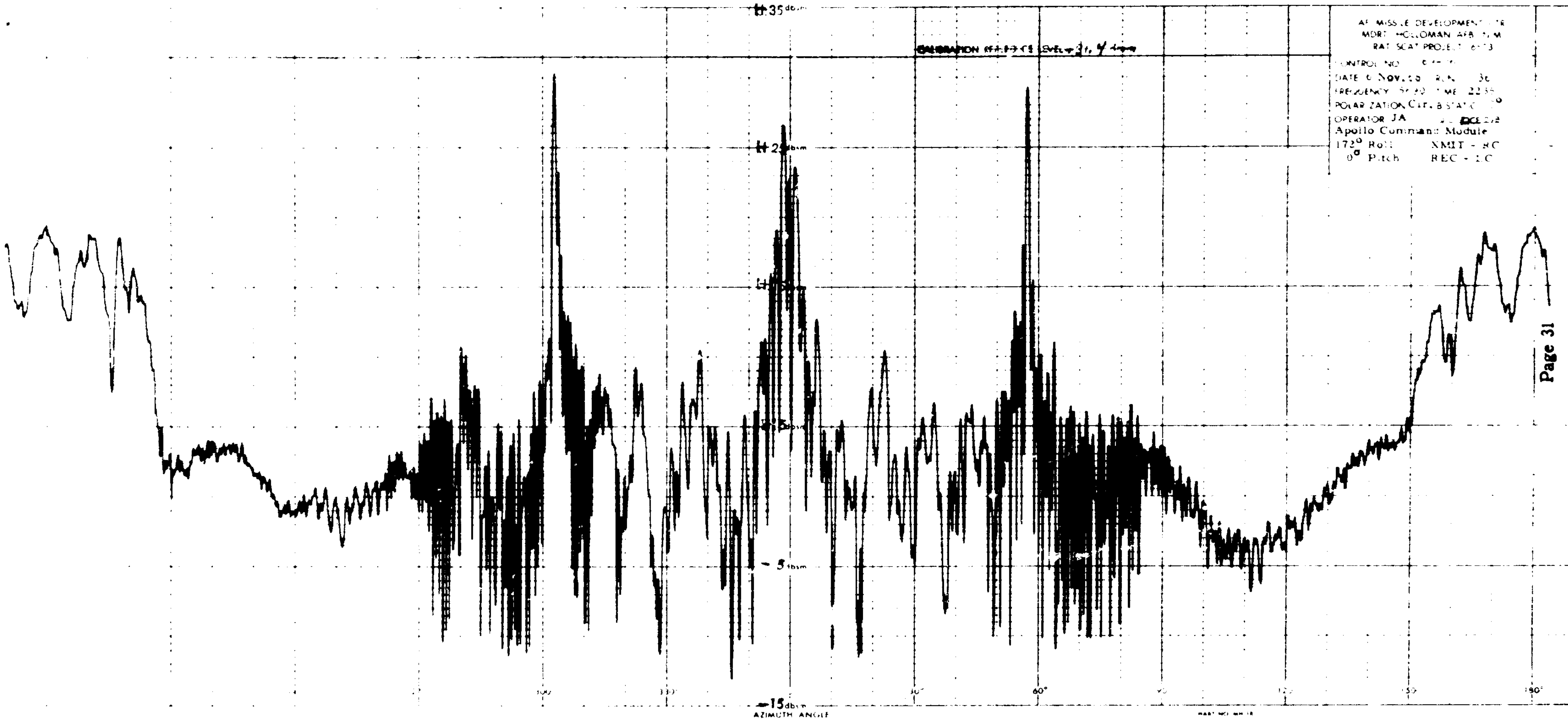
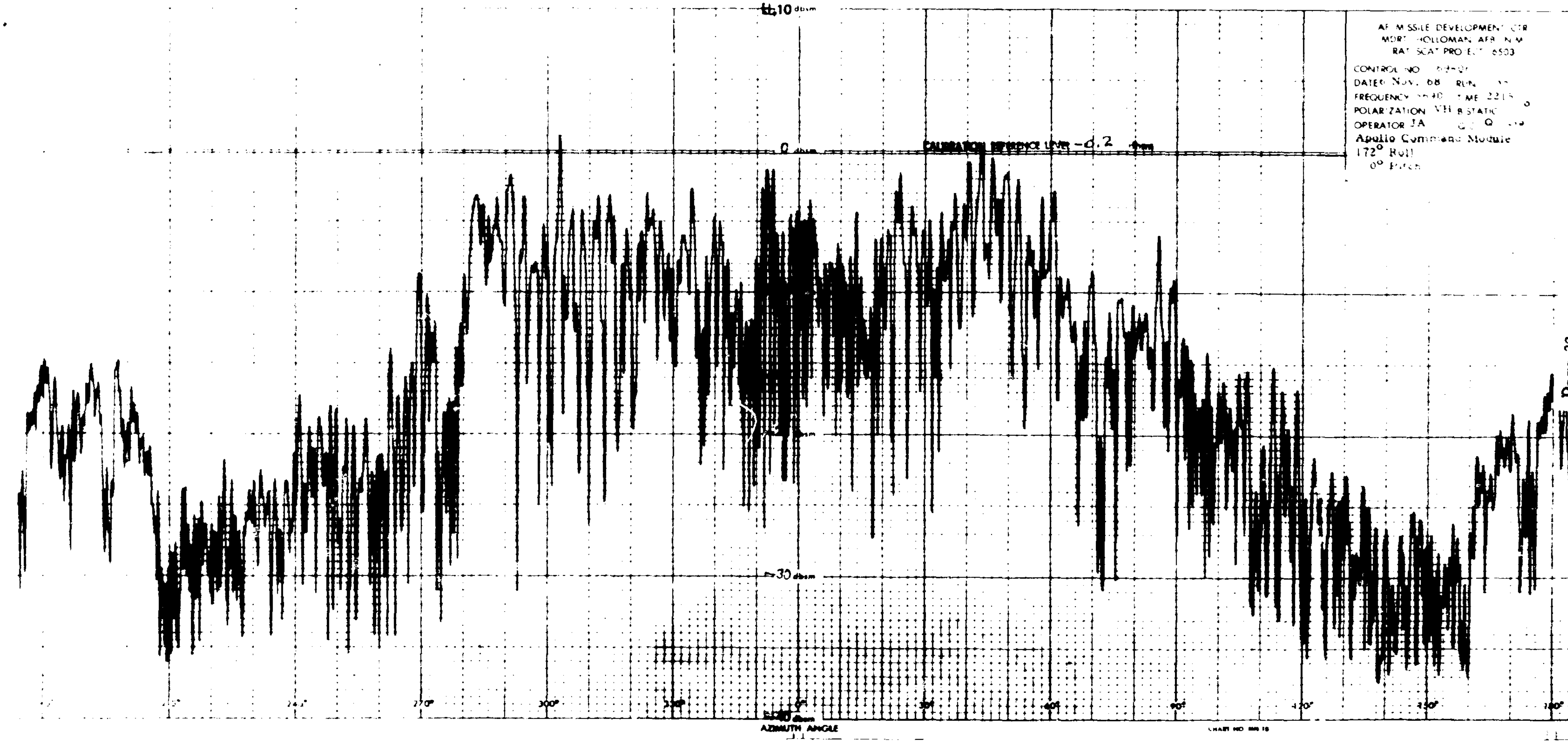
MORT HOLLOMAN AFB N M
RAT SCAT PROJECT 6523
CONTROL NO 69-BL
DATE Nov. 68 RUN
FREQUENCY
POLARIZATION V BISTATIC
OPERATOR JA QC
Apollo Command Module
172° Roll
0° Pitch
CALIBRATION REFERENCE LEVEL + 32.7 dbsm
+ 30 dbsm
+ 20 dbsm
5 dbsm
15 dbsm
AZIMUTH ANGLE
180°
210°
240°
270°
300°
330°
0°
30°
60°
90°
120°
150°
180°
Page 30


Apollo Command Module
172° Roll
0° Pitch
XMIT - RC
REC - LC
OPERATOR JA
AZIMUTH ANGLE
60°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HOLLOMAN AFB N M
RAT SCAT PROJECT 6503
CONTROL NO
DATE Nov. 68 RUN
FREQUENCY TIME 2215
POLARIZATION VH BISTATIC
OPERATOR JA
Apollo Command Module
172° Roll
0° Pitch
+10 dbsm
0 dbsm
CALIBRATION REFERENCE LEVEL -0.2 dbsm
-30 dbsm
270°
300°
0°
30°
60°
90°
120°
150°
180°
AZIMUTH ANGLE

Page 32

APPENDIX A

SITE INTRODUCTION

General

RAT SCAT is a static ground plane radar cross section measurement site, located on Alkali Flats near Holloman Air Force Base, New Mexico. It is authorized by the DOD for use by governmental agencies. It is under the auspices of Air Force Missile Development Center, HAFB, New Mexico.

A ground plane range utilizes radar energy reflected from the earth as well as radar energy traveling directly to the target through the atmosphere. When the antennas and target are adjusted to proper heights, coherent phase addition of these electromagnetic waves into a flat wave front, enhances the system sensitivity. Radar returns from objects near the earth's surface are reduced thus suppressing target area interference. Target area interference is reduced further through the use of special polyfoam mounting platforms, radar absorptive materials (RAM), and rotators located below the earth's surface (in pits).

Pulsed transmitters are employed to enable utilization of the range gated receiving system, which can selectively measure radar returns from the target area or the range displaced transfer standard. Background interference outside the target range is eliminated by range gating. Operation without background cancellation is therefore practical.

Capabilities

The RAT SCAT electronic equipment and controls are housed in a permanent building. Three separate range lengths (458 feet, 1158 feet, and 2458 feet) are provided for range variation as shown in Figure A-1. This allows the use of convenient antenna and target heights while satisfying the far field criterion for most targets. (Special 40-foot antenna towers

are attached to the building for antenna height positioning.) Further versatility is provided by two mobile equipment vans, one for monostatic range length variation and one for bistatic measurements. A duplicate set of control and data consoles in the main building enables simultaneous operation of any two of the three ranges. A summary of the RAT SCAT characteristics is contained in Table A-1.

Calibration

The normal method of calibration at RAT SCAT is to mount a primary standard (precision sphere) scatterer with radar cross section and record the corresponding signal level. Then the return from another secondary standard (corner or Luneberg lens) scatter displaced in range is recorded as a transfer standard. Both the precision standard return and the transfer standard return are recorded on the same plot. Thereafter, radar cross section calibration is determined by referencing the transfer standard return for every run. Thus every run is recalibrated. The comparisons of primary and transfer standards accomplished before and after each measurement series are identified respectively as calibration and post-calibration. If the direct ratio of primary to secondary readings is not maintained before and after the measurement series, then all runs between are invalid and must be repeated.

The calibration reference level marked on each data plot is related to the transfer standard level. This reference level may under controlled conditions differ from the actual transfer standard signal level since precision calibrated attenuation is sometimes inserted in the receiver line. When such attenuation is inserted, returns from the transfer standard are reduced to a level compatible with the scale used for the target measurements. The 50 db dynamic range of the plot is placed to include the range

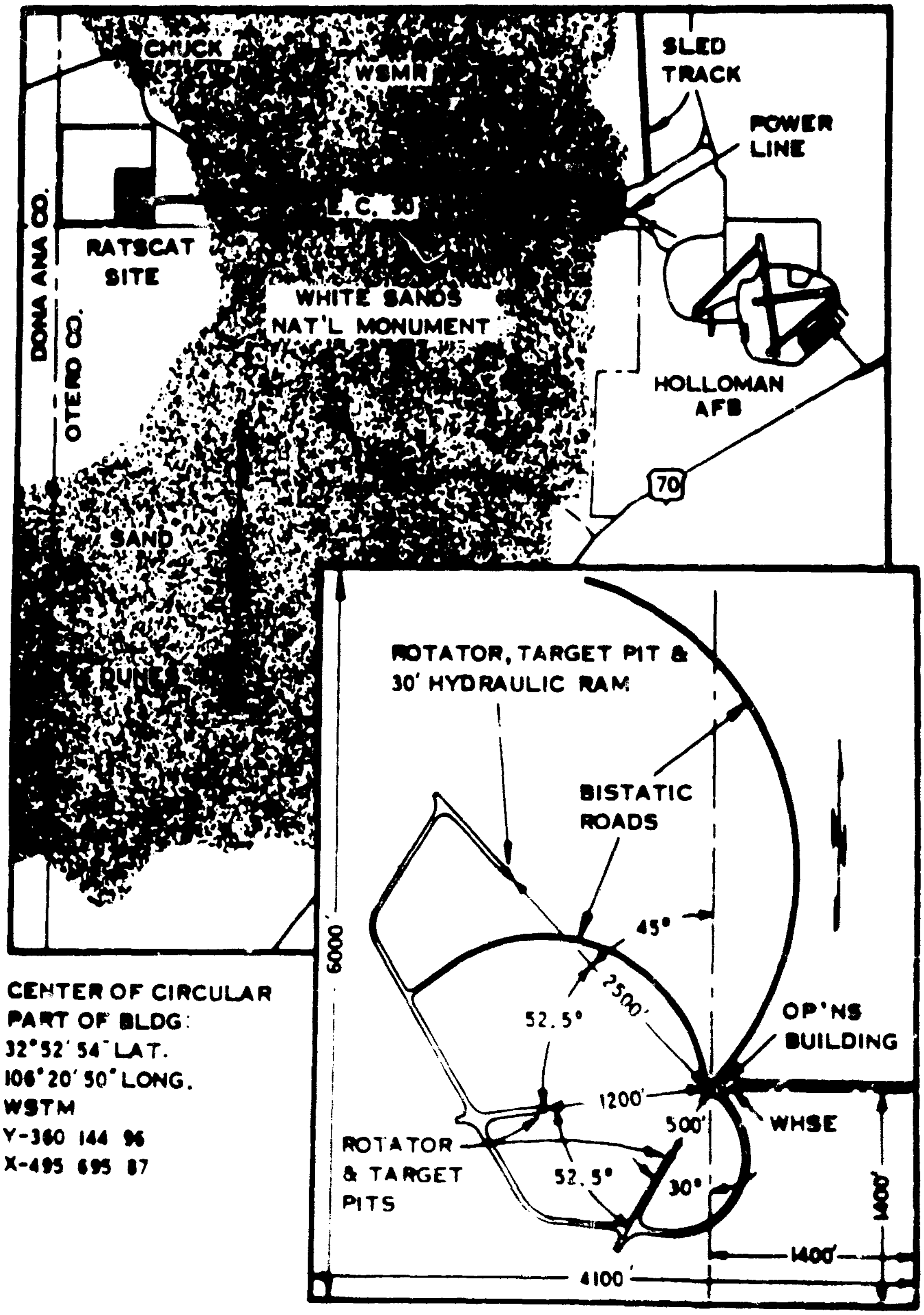


FIGURE 1: RATSCAT PROJECT 6503

TABLE A-1 RAT SCAT CHARACTERISTICS OF ELECTRONIC EQUIPMENT

Power Output	1 KW minimum
Pulse Width	0.1 to 1.0 microsecond
Pulse Repetition Frequency	500 to 5000 pps
No. of Receiving Systems	Two per Band, (one monostatic and one bistatic)
Receiver Minimum Detectable Signal	-94 to -106 dbm (proportionate to frequency)
Receiver Bandwidth	2 or 10 mc (selectable)
Range Gate Width	0.1 to 1.0 microsecond (50 to 500 feet)
Dynamic Range	50 db
Linearity	±0.5 db
Equipment Stability	0.1 db/hour (Average)
Analog Data Format	Polar and rectangular plots of cross section and phase vs aspect angle
Digital Data Format	Punched paper tape recorded at 0.1 - to 4.0 degree azimuth increments
Antennas	3-, 6-, 10-, and 16-foot parabolic dishes (smaller and larger dishes (1.5 to 30-foot for special tests)
Antenna Feeds	Log periodic and horns all with VSWR less than 2.0 to 1.0
Polarization	Horizontal, vertical, circular, elliptical in any cross combination of transmitting and receiving configuration.
Background Level	As low as -80 dbsm (frequency dependent)
Background Reduction	Tuned columns and vector substraction by using phase and amplitude measurements to reduce background by 20 db
Phase Measurement	Unique RAT SCAT capability for vector subtraction or scattering matrix applications. Band 4 only.
Azimuth Resolution	0.1 degree
Maximum Target Weight	10,000 pounds
Target Size	Greater than 60-foot length
Bistatic capability	458-, 1158-, and 2458-foot range for 0- to 120-degree bistatic angle
Frequency Coverage	100 to 11,500 mc (7 bands)

Band 1 - 100 to 250 mc Band 2 - 250 to 500 mc
Band 3 - 500 to 1000 mc Band 4 - 1000 to 2000 mc
Band 5 - 2000 to 4000 mc Band 6 - 4000 mc to 8000 mc
Band 7 - 8000 mc to 11,500 mc

Range Length	300 feet minimum

Building Pit 1 - 458 ft Building Pit 2 - 1158 ft
Building Pit 3 - 2458 ft Monostatic Van Pits 1, 2, or 3 - variable Range Length

of returns expected from the vehicle being measured. In some cases 2 runs are necessary to be plotted for direct overlay to include the dynamic range of the vehicle if it exceeds 50 db. Calibration plots are included with the target data when requested by the user.

The sphere calibration plots will not necessarily be straight lines. If the background return is within 20 db of the sphere return, for example, a variation in sphere return of approximately ± 1 db can result. For calibration the sphere is intentionally placed at least 1/2 wavelength off the center of table rotation to insure sufficient phasing with the background return. The average sphere return is then chosen for a calibration level. This avoids the peak errors involved with coherent addition of sphere return and background return and allows the minimum errors involved with non-coherent addition of the returns. This is indicated in Figure A-2.

Operating Procedures

The following step-by-step procedure is standard in obtaining monostatic radar cross section measurements after frequency, feeds, antennas, antenna height, target height, and pit (range length) have been chosen:

1. Calibration - As described in previous section.

2. Horizontal and Vertical Probes (field strength measurements at the target area) - Horizontal probes at the target area have been shown to be redundant for azimuthal boresighting. For this reason, these probes are taken only upon request for examination of near field effects. Vertical probes are taken at the target area to determine power variation as a function of target height. If necessary, antenna height is varied to obtain an acceptable vertical probe which then necessitates a new calibration.

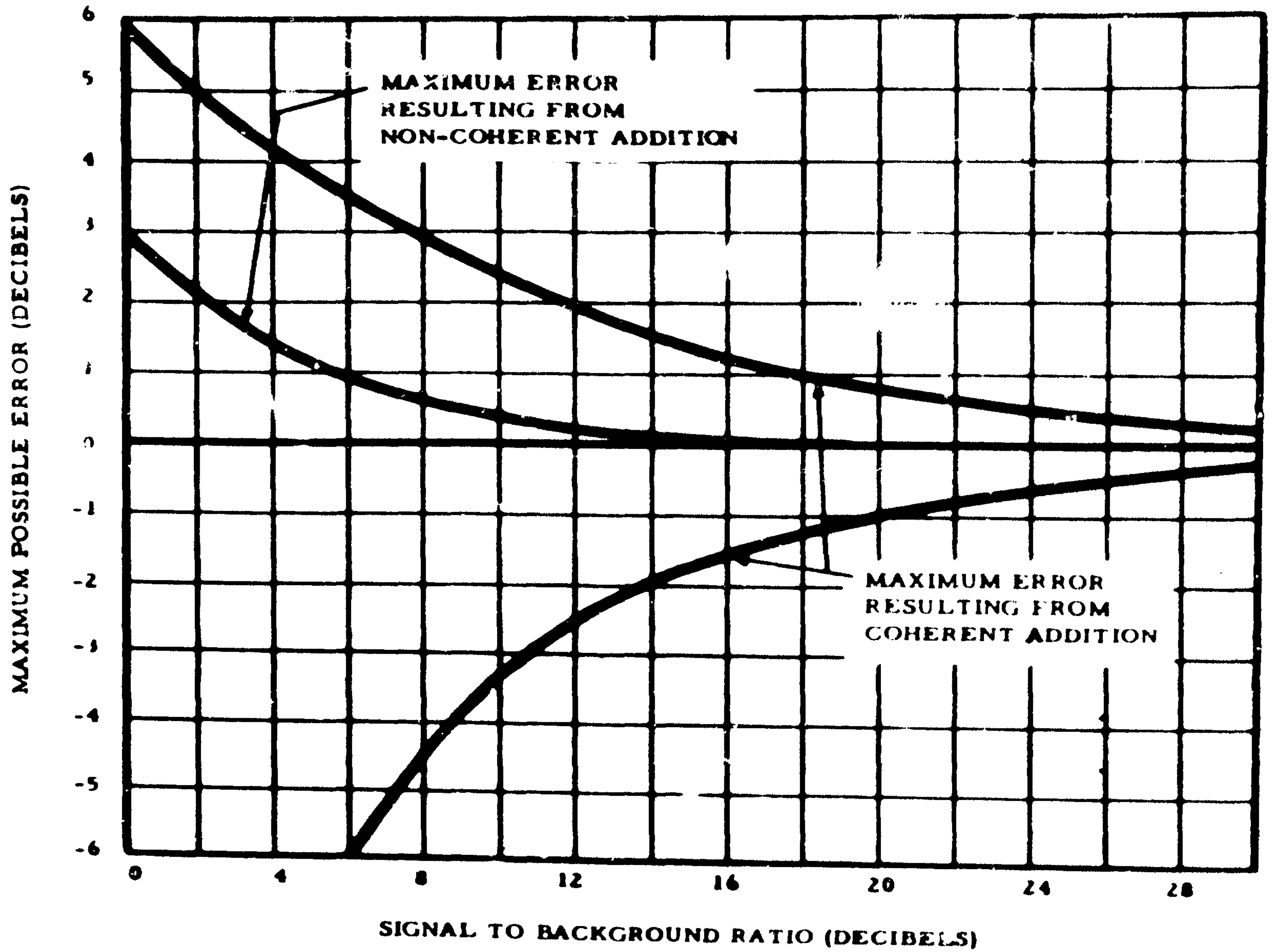


FIGURE A-2 PLOT OF ERROR INDUCED BY BACKGROUND INTERFERENCE

3. **Background** - The background level with the target mount in place is measured in each polarization to be used.

4. **Measurement** - The measurement is made with the vehicle in the position previously occupied by the primary standard.

5. **Calibration** - The primary calibration is repeated to verify calibration (post cal.).

APPENDIX B

TARGET ORIENTATION AND DATA FORMAT

Coordinate System

The coordinate system described herein has been adopted as a standard for RAT SCAT operations. The system is referenced both to the vehicle being measured and to the measurement site.

Vehicle Reference

A three-axis system, referenced to an arbitrary vehicle, is illustrated in Figure B-1. In this system three mutually perpendicular planes (yaw, pitch, and roll) are passed through the vehicle so that the pitch and yaw planes mutually intersect on the longitudinal axis of the vehicle. These planes remain fixed with respect to the vehicle, regardless of vehicle rotation with respect to the radar or ground plane. The yaw plane, which includes the pitch axis and the roll axis, is numbered from 0 degrees to 360 degrees in a clockwise direction when the vehicle is viewed from the above. The nose-on aspect corresponds to 0 degrees, the starboard side of the vehicle corresponds to 90 degrees, and the port side to 270 degrees. The pitch plane, which contains the roll axis and the yaw axis is numbered from 0 degrees to ± 180 degrees; the + 90 degree point is below the center line, and the - 90 degree point is above the center line. The roll plane contains the yaw axis and the pitch axis. It is numbered from 0 degrees to 360 degrees, and the numbers increase in a counterclockwise direction when the vehicle is viewed from the rear.

Site Reference

As previously stated the coordinate system is fixed with respect to the vehicle. It is referenced to the site by means of three index marks. The exact value of any of the three angles is determined by noting the value of the vehicle coordinate opposite the index marks. Index marks

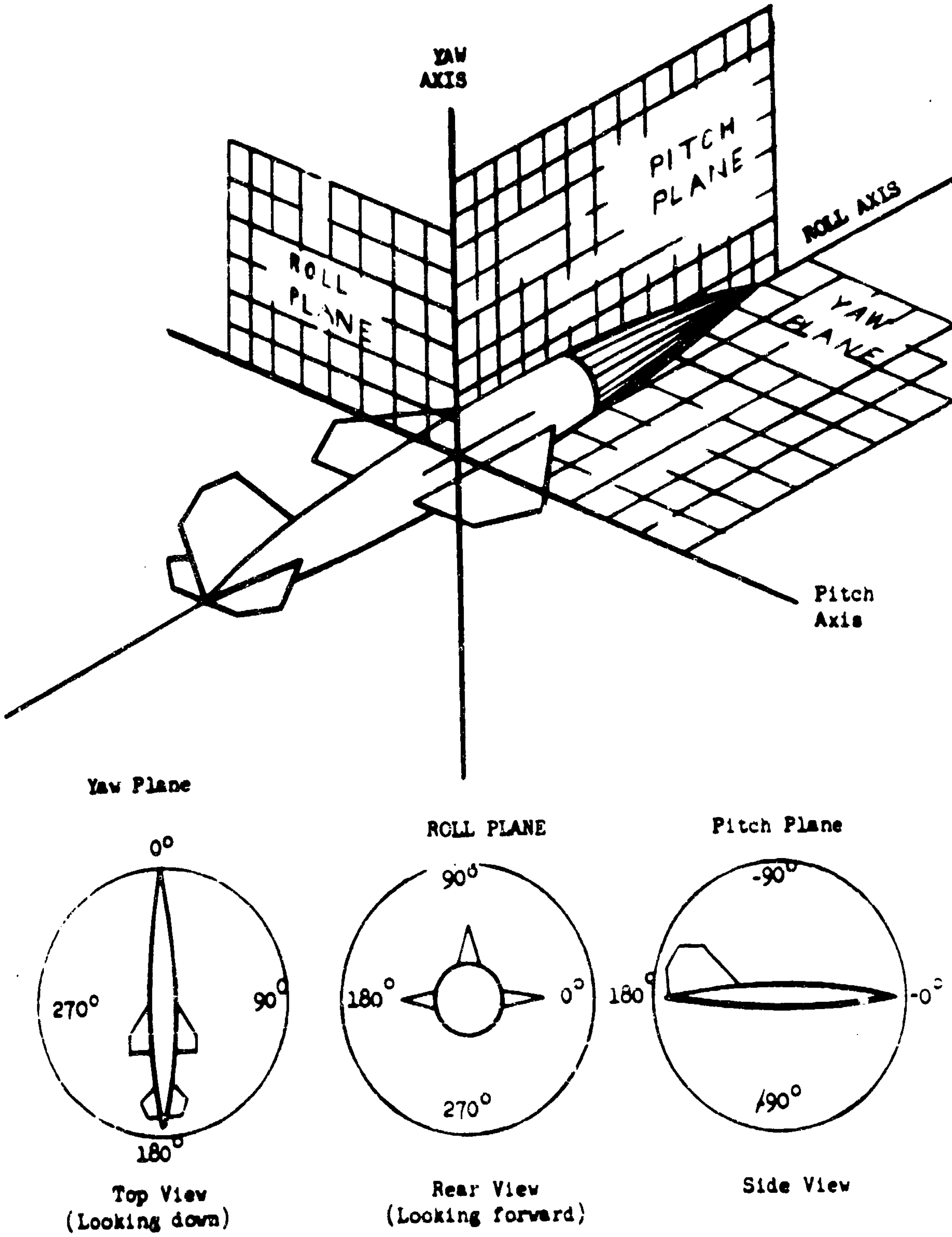


FIGURE B-1 VEHICLE COORDINATE SYSTEM

come from such devices as bubble levels, inclinometers and transits.

As illustrated in Figure B-2, the index for roll angles is normal to the axis of rotation. As illustrated in Figure B-3, the index for pitch angles is normal to the axis of rotation and in line with the apparent source of radiation. For measurements at the RAT SCAT Site, targets can be mounted to provide desired pitch and roll angles.

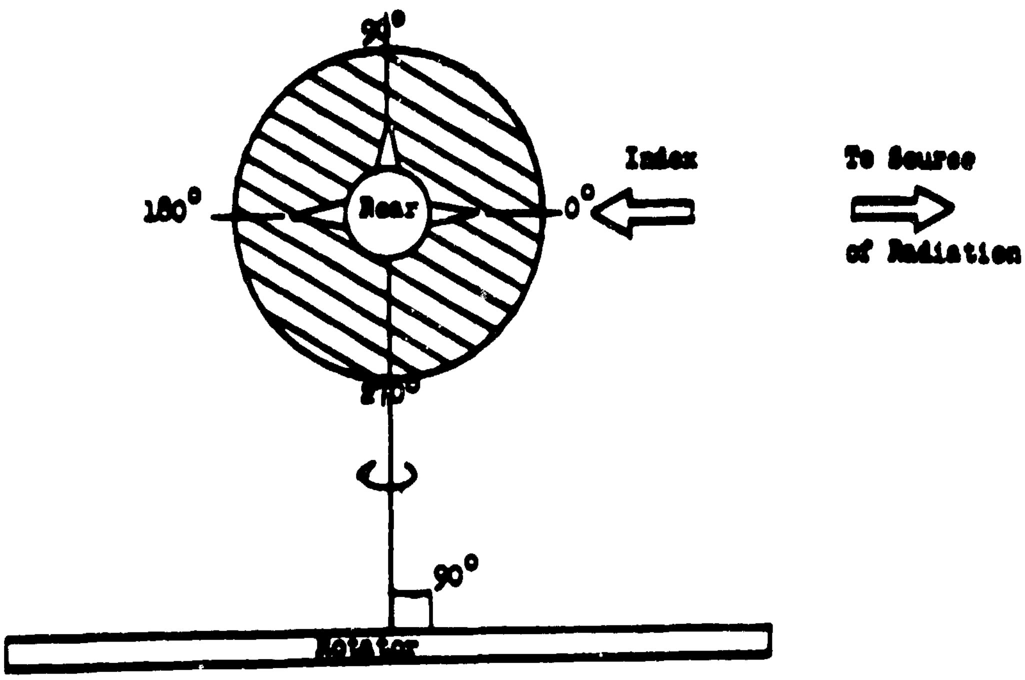
Coordinate System Tilt

For small targets another angle, tilt, can be utilized in recording useful data. This angle, equipment-limited to less than 15 degrees, is formed by the axis of rotation and the normal to the line of sight to the apparent source of radiation. Since, in a ground plane range, radiation can be considered to emanate from a point with zero height directly beneath the antennas, a zero-degree tilted axis of rotation is slightly off the geometrical vertical. This small deviation from the geometrical vertical is neglected in the following discussions.

A target mounted with a pitch angle other than zero displaces the yaw axis from the vertical, but not the axis of rotation. The axis of rotation is displaced from the vertical only when non-zero tilt is employed. Tilting toward the radar is considered positive tilt and away from the radar is negative tilt. For monostatic measurements tilt will be measured in the vertical plane containing the line of sight between the radar and the target. The difference between pitch and tilt is shown in Figure B-4.

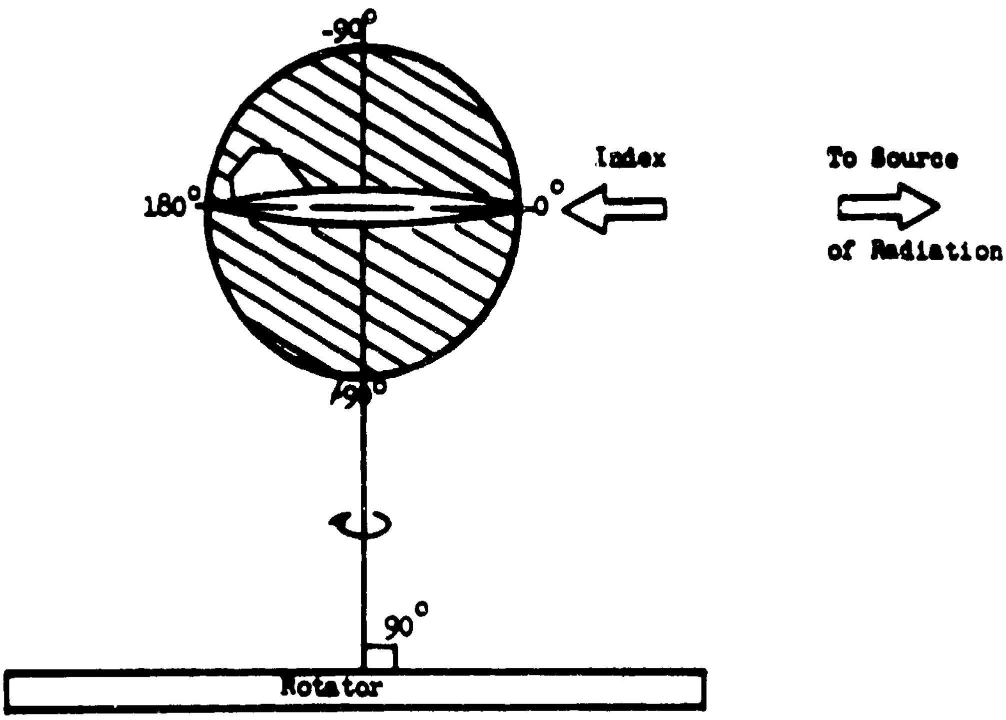
Data Format

Data recorders obtain azimuth angle information by means of precision synchro signals from the position of the rotating table. The line of sight from the antennas to the center of the rotator, as illustrated in



NOTE: The roll scale is fixed to the vehicle. The amount of roll is determined by noting the number of degrees opposite the index. Clockwise rotation of the target (when viewed from the rear) increases the roll angle.

FIGURE B-2 TARGET ORIENTATION - ROLL



NOTE: The pitch scale is fixed to the vehicle.
The number of degrees of pitch is determined
by noting the scale value opposite the index.

FIGURE B-3 TARGET ORIENTATION - PITCH

Figure B-5, indexes azimuth angles. As used here the term azimuth refers to the position of the target rotator table. With zero degrees of pitch and roll, azimuth and yaw are identical. It is standard practice to turn the rotator in a clockwise (cw) direction as viewed from above. Consequently, the azimuth angle varies, for example from 180 degrees (tail-on) to 90 degrees (starboard-side) to 0 degrees (nose-on) to 270 degrees (port-side).

Polar and Rectilinear Plots

Essential information pertinent to each plot is contained in the information block located in the upper right hand corner of the rectilinear plots and in the second quadrant of the polar plots. Each rectilinear plot has the recording of the return from the left side of the vehicle on the left side of the plot, 0 degrees at the center, and the recording of the return from the right side of the vehicle on the right side of the plot; 180 degrees (tail-on) appears at the right and left extremeties of the plot, as shown in Figure B-6. Since the paper moves from left to right under the recorder pen, it should be noted that measurements are limited at 180 degrees in order to obtain continuous measurements on the recorder paper. The table on the polar recorder is rotated in the same directions as the target so the 90-degree point appears on the right side of the polar plot, the 270 degree point on the left, and the zero or 360 degree point at the top of the plot.

Digital Printouts

At the users request, radar cross section data are available in the digital form of punched paper tapes. The 11/16 inch tape is punched with the standard TELETYPE COMMUNICATIONS (Type 3) code in which 5-bit characters are used. Sigma servo positions, quantitised to tenths of a db, are recorded at specified azimuthal increments (.1,

NOTE: 1) Axis of rotation is always collinear with Azimuth Axis.
2) Nose-on points towards source of radiation in both cases.

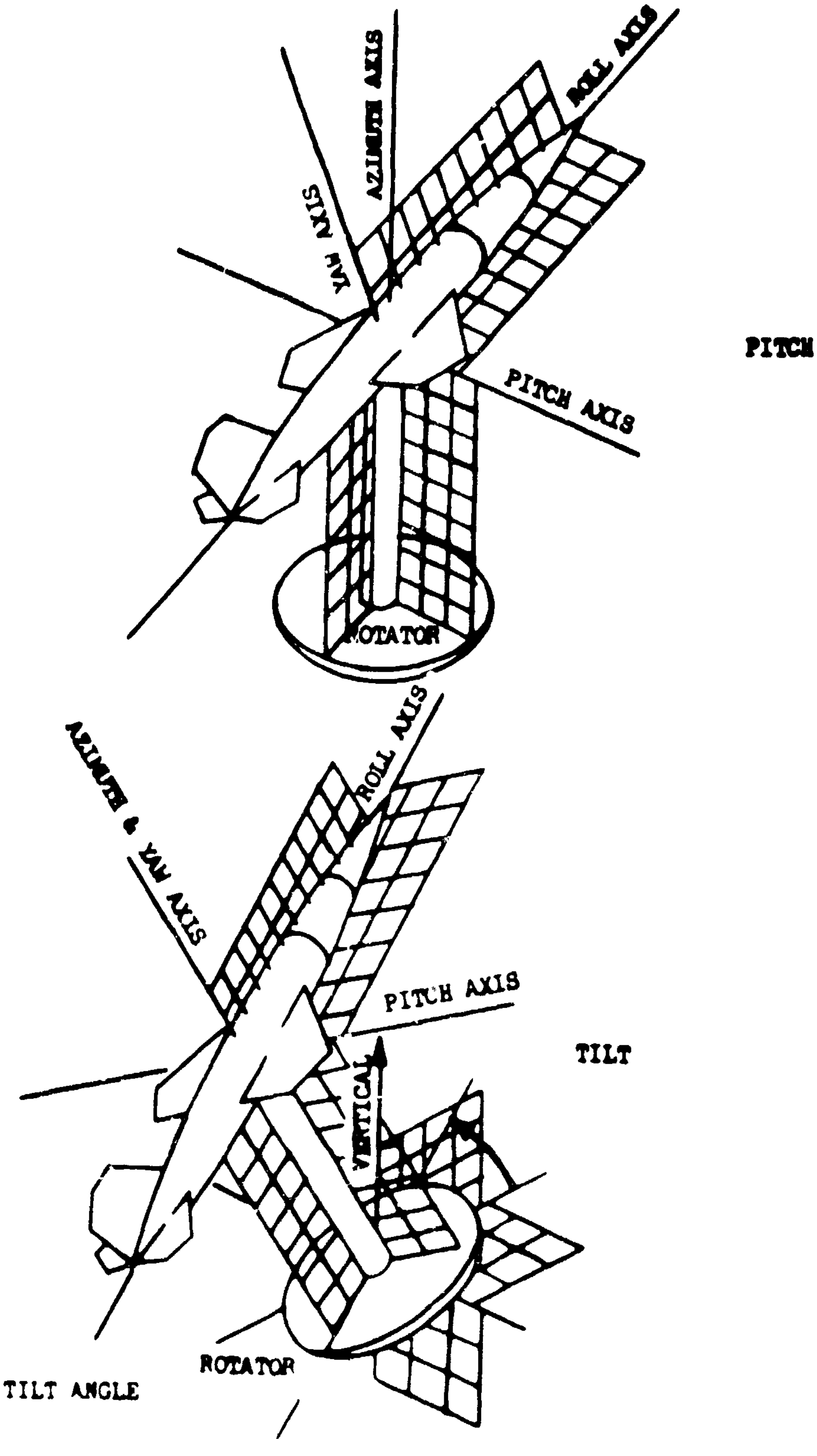
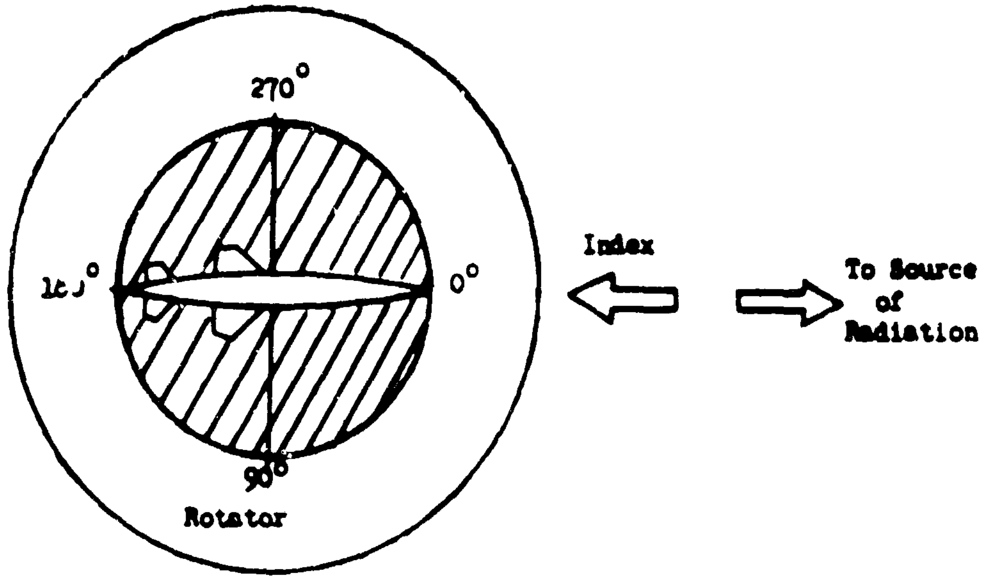


FIGURE B-4 COMPARISON OF PITCH AND TILT ORIENTATIONS



NOTE: The azimuth scale is fixed to the target rotator. The azimuth value is determined by noting the value of the scale opposite the index mark as the rotatcr and scale revolve. The index is the line-of-sight from the radar antennas to the center of the rotator. (Azimuth angle data are transmitted to the data recorders by means of synchro signals.) The standard direction of rotation will be clockwise.

FIGURE B-5 TARGET ORIENTATION - AZIMUTH

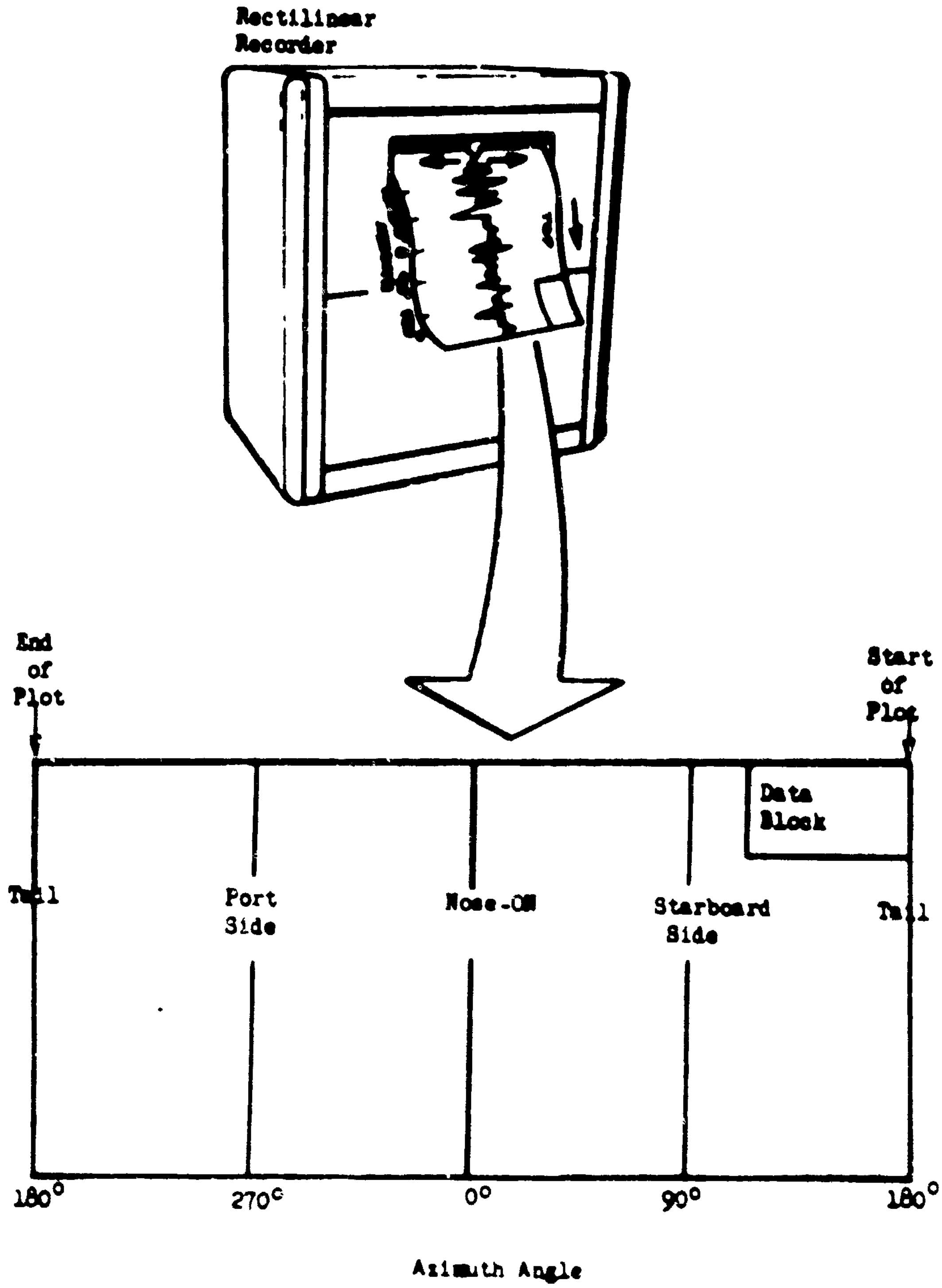


FIGURE B-6 FORMAT FOR RECTILINEAR PLOTS

.2, .4, 1.1, 2.0, or 4.0 degrees). Each of these recordings are preceded by the corresponding value of the rotator azimuth position. Since all three recorders are synchronized to azimuth positions of the rotator, the digital printouts, like the rectilinear plots, begin at the tail end of the vehicle and progress as if the vehicle were turning clockwise.

Header Format. Each digital data-run has a section of the punched paper tape, called the header, preceding it that contains information identifying the run. A format along with a standard set of symbols has been chosen which facilitates identification of different portions of the header. It also puts the paper tape in a form that could be used as an input to a digital computer. Symbols used in punched paper tape:

Carriage Return	
Line Feed	
Figures	
Letters	
Start Identification Information	(
Stop Identification Information	)
Start Data (exclamation point)	!
Plus Sign (quotation mark)	"
Minus Sign (dash)	-
Secondary Standard (ampersand)	&
Primary Standard (dollar sign)	$
Target (question mark)	?

The following format, consisting basically of three sections provides a uniform procedure for recording and identifying data:

a) Identification Information: This includes pertinent information applying to a particular run. This section, enclosed in parenthesis, includes control number, run number, date, time polarization, frequency, and brief description.

b) Transfer Standard Data: Data representing secondary signal levels follow the identification information. These data are preceded on the recording tape by an identifying symbol, ampersand (&), followed by a plus or minus sign, three digits, and an exclamation point, such as &" 40.0!. In this example "40.0 is a conversion constant. Conversion constants are discussed in the section below entitled Calibrating Digital Tape.

c) Target Data: Target data format is identical to transfer standard data format, with the exception that the ampersand is replaced by a dollar sign($) or a question mark (?), depending on the object being measured. The former is used for primary standards; the latter for vehicle, background, etc.

Calibrating Digital Tapes. Unlike the graphical forms of data, the digital printouts are not calibrated, and as such do not represent the actual radar cross sections. Information from the printouts can be calibrated, however, by subtracting the conversion constant from one-tenth the value of each digital printout. The conversion constant follows the symbol identifying the type of data. It is important to note that, as the recording tape progresses, each conversion constant supersedes all prior conversion constants. This calibration method is illustrated by the following example. Suppose one-tenth the value of the target signal level printout corresponding to 180 degrees is +58.0, and the conversion constant is "50.0 (decoded this equals 50.0 dbsm). Then the actual radar cross section of the target at 180 degrees would be +8 dbsm.

Calibration of Magnetic Tape will be as specified by each individual user.

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13. ABSTRACT

Radar cross section measurements of an Apollo Command Module mock-up were obtained at RAT SCAT. Measurements were taken at frequencies of 2200 and 5690 megahertz with both vertical and horizontal antenna polarizations. In addition, circular polarization and cross polarization measurements were obtained at 5690 megahertz. Target orientations measured were 0 degree pitch; 53, 106, 136 and 172 degrees roll. This report contains no analysis of the data.

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